4 Diubal

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**Add-on Module** 

# RF-STEEL Plastic

Plastic Design According to the Partial Internal Forces Method (PIFM)

### Program Description

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## I. Introduction

### 1.1 Add-on Module RF-STEEL Plastic

A common way to design cross-sections is the elastic-plastic method. For the calculation of the internal forces  $S_d$ , linear elastic material behavior is assumed, for the calculation of the resistances  $R_d$  the elastic-perfectly plastic material behavior. Thus, the reserves of the cross-section are used, but the possibly existing plastic reserves of the system are not considered.

The ultimate limit state occurs when the limit internal forces in the fully plastic state are reached. It is necessary to verify that the internal forces under consideration of the interaction do not result in exceeding the limiting internal forces in the fully plastic state.

In RF-STEEL Plastic, the following design methods are available:

- Cross-sections consisting of three or two plates (I-, C-, Z-, L-sections, channels, tees), flat steel, pipes, and hollow sections according to the Partial Internal Forces Method (PIFM) with redistribution by KINDMANN/FRICKEL
- Elliptical cross-sections with analytic non-linear optimization procedure
- Simplex Method for general cross-sections.

For this design method, all combinations of internal forces are considered. The design ratio of each section is shown in the clearly-arranged tables and in the RFEM graphic, allowing you to infer the utilization of certain members at one glance. For each design section, detailed information on interaction (for example, the plastic internal forces) is shown.

If necessary, the module carries out an optimization of the cross-sections and exports the changed cross-sections to RFEM. Using the design cases, you can analyze separate structural components in complex structures or analyze variants.

RF-STEEL Plastic is an add-on module integrated in RFEM. Thus, the design-relevant input data is already preset when you start the module. After the design, you can evaluate the results in the graphical user interface of RFEM. Finally, the analyses can be documented in the global printout report, from determination of internal forces to design.

We hope you enjoy working with RF-STEEL Plastic.

Your DLUBAL Team

### 1.2 RF-STEEL Plastic Team

The following people were involved in the development of RF-STEEL Plastic:

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### 1.3 Using the Manual

Topics like installation, graphical user interface, results evaluation, and printout are described in the manual of the main program RFEM. The present manual focuses on typical features of the RF-STEEL Plastic add-on module.

The descriptions in this manual follow the sequence and structure of the module's input and results windows. In the text, the **buttons** are given in square brackets, for example [View mode]. At the same time, they are pictured on the left. The **Expressions** that appear in dialog boxes, windows, and menus are set in *italics* to clarify the explanations.

At the end of the manual, you find the index. If you still cannot find what you are looking for, please check our website www.dlubal.com where you can go through the FAQ pages and find a solution by using various filter criteria.

### 1.4 Opening the RF-STEEL Plastic Module

In RFEM, you have the following possibilities to start the add-on module RF-STEEL Plastic.

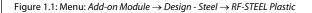
#### Menu

۲

To open the add-on module, you can select in the RFEM menu

Add-on Module  $\rightarrow$  Design - Steel  $\rightarrow$  RF-STEEL Plastic.

Add	-on Modules Window	H	elp		
<b>*</b> 0	Current Module			• < > <u>P</u> 🛓	ᆇ 💯   😪 📾 📾 🦉 📾 📾 🔛   🗞 🖨
	Design - Steel	•	<i>.</i>	RF-STEEL Surfaces	General stress analysis of steel surfaces
	Design - Concrete	×	Ľ	RF-STEEL Members	General stress analysis of steel members
	Design - Timber	►	LEC	RF-STEEL EC3	Design of steel members according to Eurocode 3
	Design - Aluminium	×	AISC	RF-STEEL AISC	Design of steel members according to AISC (LRFD or ASD
	Dynamic	×	ALSC.	RF-STEEL IS	Design of steel members according to IS
	Connections	×	SIA	RF-STEEL SIA	Design of steel members according to SIA
	Foundations	×	1BS	RF-STEEL BS	Design of steel members according to BS
	Stability	•	168	RF-STEEL GB	Design of steel members according to GE
	Towers	×	Is	RF-STEEL CS	Design of steel members according to C
	Others	•	TAS	RF-STEEL AS	Design of steel members according to As
	External Modules	►	NIC	RF-STEEL NTC-DF	Design of steel members according to NTC-DF
	Stand-Alone Programs	•	Isp	RF-STEEL SP	Design of steel members according to SF
			PIRM	RF-STEEL Plastic	Design of steel members according to PIFM
			SANS	RF-STEEL SANS (Dem	o version) Design of steel members according to SANS
			1FD	RF-STEEL Fatigue Me	embers (Demo version) Fatigue design of steel members
			1	RF-KAPPA	Flexural buckling analysis
			1	RF-LTB	Lateral-torsional and torsional-flexural buckling analysis
			₽. Fe	RF-FE-LTB L	ateral-torsional and torsional-flexural buckling analysis by FEM
			I.	RF-EL-PL	Elastic-plastic design
				RF-C-TO-T	Analysis of limit slenderness ratios (c/t
				RF-PLATE-BUCKLING	Plate buckling analysis





#### Navigator

Alternatively, you can start the add-on module in the Data navigator by clicking

```
Add-on Modules \rightarrow RF-STEEL Plastic.
```

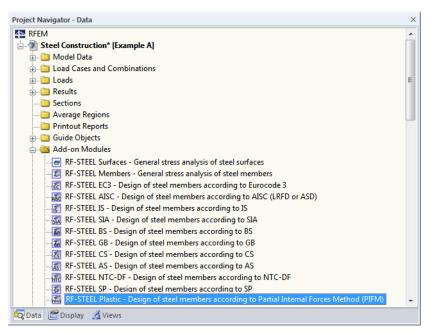


Figure 1.2: Data navigator: Add-on Module  $\rightarrow$  RF-STEEL Plastic

#### Panel

If results from RF-STEEL Plastic are already available in the RFEM model, you can also open the design module from the panel:

First, set the relevant RF-STEEL Plastic design case in the load case list of the RFEM toolbar. Then, click the [Show Results] button to graphically show the design criterion on the members.

If the results display is activated, the panel is available, too. Now you can click [RF-STEEL Plastic] in the panel to open the module.

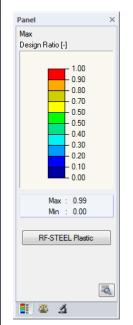


Figure 1.3: Panel button [RF-STEEL Plastic]



RF-STEEL Plastic CA1 - PIFM LC1 - Self-weight LC2 - Imposed load CO1 - 1.35\*LC1 + 1.5\*LC2

RF-STEEL Plastic CA2 - Simplex Method



# 2. Input Data

When you start the add-on module, a new window opens. In this window, a navigator is displayed on the left that manages the available input and output windows. The drop-down list above the navigator contains the design cases (see Chapter 7.1, page 38).

The design-relevant data is defined in several input windows. When you open RF-STEEL Plastic for the first time, the following parameters are imported automatically:

- Members and sets of members
- Load cases, load combinations, and result combinations
- Materials
- Cross-sections
- Internal forces (in the background, if calculated).

To select a window, click the corresponding entry in the navigator. To go to the previous or next window, use the buttons shown on the left. You can also use the function keys to select the next [F2] or previous [F3] window.

To save the results, click [OK]. Thus, you exit RF-STEEL Plastic and return to the main program. To exit the module without saving the new data, click [Cancel].

### 2.1 General Data

In the 1.1 *General Data* window, you select the members, sets of members, and actions that you want to analyze. The tabs manage the load cases, load combinations, and result combinations for the various checks.

CA1 - Design of steel members	- 1.1 General Data	
input Data General Data Materials Cross-Sections	Design of           Member:         1:8,11-18,21-28,31-46,51-64,66:69,71-74,81-83,91-1           Set:         Image: Im	Plastic
	Image: IC2       Show Load         Image: IC2       Show Load         Image: IC2       Which are stable in +Y         Image: IC2       Show Are stable in +Y         Image: IC2       Image: IC2         Image: IC2       Image: IC2         Image: IC2	Ratic analysis of members and sets of members cross sortion optimization Parts list
	At (27) - (27) (25)	

Figure 2.1: Window 1.1 General Data

```
Cancel To
```

OK



#### Design of

Design of			
Members:	1-8,11-18,21-28,31-46,51-64,66-69	🗞 🗙	🔲 All
Sets:	1-3,5-8	🏹 🗙 街	🔽 All

Figure 2.2: Design of members and sets of members

\$

<u>~</u>

>

The design can be carried out for *Members* as well as for *Sets of Members*. If you want to design only particular objects, clear the *All* check box. Now you can access the text boxes to enter the numbers of the relevant members or sets of members. To select the list of the preset numbers, double-click in the text box and overwrite the list by manually entering the numbers. Alternatively, you can select the objects graphically in the RFEM work window upon clicking [^].

When you design a set of members, the program determines the extreme values of all members contained in the set of members. The according results are shown in the results windows 2.3 Design by Set of Members, 3.2 Governing Internal Forces by Set of Members, and 4.2 Parts List by Set of Members.

To define a new set of members, click [New]. The dialog box already known from RFEM appears where you can specify the parameters for a set of members.

#### **Ultimate Limit State - Existing Load Cases and Combinations**

This dialog box section contains all load cases, load combinations, and result combinations created in RFEM.

To transfer the selected entries to the *To Design* section, click  $[\blacktriangleright]$ . Alternatively, you can just double-click the entries. The  $[\blacktriangleright \blacktriangleright]$  button transfers the complete list to the right.

To transfer multiple entries at once, select them while pressing the [Ctrl] key, as common in Windows applications.

If a load case is highlighted in red, for example LC 8-10 in Figure 2.1, it means that it cannot be designed. This happens when the load cases are defined without any load data or contain only imperfections. When you transfer such a load case, a corresponding warning appears.

At the end of the list, several filter options are available. They will help you assign the entries sorted according to load cases, load combinations, or action categories. The buttons have the following functions:

Selects all cases in the list
Inverts selection of load cases

Table 2.1: Buttons in the tab Ultimate Limit State

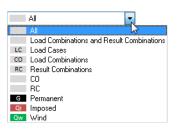
#### **Ultimate Limit State - Selected for Design**

The section on the right contains the load cases, load combinations, and result combinations selected for design. To remove selected entries from the list, click [ $\blacktriangleleft$ ] or double-click the entries. To transfer the entire list to the left, click [ $\blacktriangleleft \triangleleft$ ].

The design of an enveloping max/min result combination is performed faster than the design of all available load cases and load combinations. However, the influence of the contained load cases and load combinations is difficult to discern.

#### Comment

In this text box, you can type user-defined notes describing, for example, the current design case.





Result combination



### 2.2 Materials

The window is subdivided into two parts. The upper part lists all materials created in RFEM. The *Material Properties* dialog box section shows the properties of the current material, that is, the table row currently selected in the upper section.

	A			В				
Material	Material					-		
No.	Description		Con	nment				
1	Steel S 235   EN 10025-2:2004-11							
2	Steel S 355   EN 10025-2:2004-11					-		
3	Concrete C30/37   EN 1992-1-1:2004/AC:2010							
				(	🛃 🗣 🐧 💿			
	roperties							
3 Main Pr						•		
	ulus of Elasticity	E	210000.0					
	ar Modulus	G	80769.2	N/mm <sup>2</sup>				
	son 's Ratio	v	0.300					
	cific Weight	γ		kN/m <sup>3</sup>				
	ficient of Thermal Expansion	α	1.2000E-05	1/K		14		
	al Safety Factor	7M	1.00			Ш. н	aterial No. 1 used in	
	nal Properties							
	ficient for Limiting Stresses of Welds	αw	0.950			C	ross-sections No.:	
	elation Factor for Fillet Welds	βw	0.800			. 6	.6.7.9.10.12.13.15.	17
	kness Range t ≤ 1.60 cm				1			
	eld Strength	fy		kN/cm <sup>2</sup>			lembers No.:	
	timate Strength	fu	36.00	kN/cm <sup>2</sup>				
	kness Range t > 1.60 cm and t $\leq$ 4.00 cm					1	.2.4-7.11.12.14-17.	21,22,24-27,31-40,
	eld Strength	fy		kN/cm <sup>2</sup>				
	timate Strength	fu	36.00	kN/cm <sup>2</sup>		S	ets of members No.	
	kness Range t > 4.00 cm and t ≤ 10.00 cm							
	eld Strength	fy		kN/cm <sup>2</sup>				
U	timate Strength	fu	36.00	kN/cm <sup>2</sup>				
E Thick	kness Range t > 10.00 cm and t ≤ 15.00 cm					Σ	Lengths:	Σ Masses:
— Yie	eld Strength	fy	19.50	kN/cm <sup>2</sup>			483.37 [m]	17.173 [t]
U	timate Strength	fu	35.00	kN/cm <sup>2</sup>				
Thick	kness Ranget > 15.00 cm and t ≤ 20.00 cm							
— Yie	eld Strength	fy	18.50	kN/cm <sup>2</sup>				
1.04	timate Strength	fu		kN/cm <sup>2</sup>		-		

Figure 2.3: Window 1.2 Materials

Materials that will not be used in the design are displayed in grey, materials that are not allowed in red, and modified materials in blue.

The material properties required for the determination of internal forces are described in Chapter 4.3 of the RFEM manual (*Main Properties*). The material properties required for design are stored in the global material library. These values are preset (*Additional Properties*).

To adjust the units and decimal places of material properties and stresses, select in the module's menu

Settings  $\rightarrow$  Units and Decimal Places (see Chapter 7.3, page 42).

#### **Material Description**

The materials defined in RFEM are preset but can be changed at any time. To do this, click the material in column A. Then, click [♥] or press function key [F7] to open the material list.

DIN 18800:1990-11 DIN 18800:1990-11

A	
Material	
Description	
Steel S 235   EN 10025-2:2004-11	F
Steel S 235	10
Steel S 275	
Steel S 355	
Fine Grain Steel S 275 N	
Fine Grain Steel S 275 M	
Fine Grain Steel S 355 N	
Fine Grain Steel S 355 M	
Fine Grain Steel S 460 N	
Fine Grain Steel S 460 M	
Improved Steel C 35+N	

Figure 2.4: List of materials



You can select only materials from the "Steel" category.

After you import a material, the design relevant Material Properties are updated.

If you change the material description manually and your entry is stored in the material library, RF-STEEL Plastic will import the material properties, too.

It is principally not possible to edit the material properties in RF-STEEL Plastic.

#### **Material Library**

Numerous materials are already available in the library. To open the library, select

 $Edit \rightarrow Material Library$ 

or use the button shown on the left.

1

Filter Materia	al to Select				
Material category group: Mater	ial Description	Standard			
Metal - Ste	eel S 235	🔯 EN 1	0025-2:2004-11		į.
	el S 275		0025-2:2004-11		
Interial entergany:	el S 355		0025-2:2004-11		
	el S 450		0025-2:2004-11		
	el S 185		0025-2:2004-11		
Standard group:					
IO EN	el S 235 JR		0025-2:2004-11		
	el S 235 J0		0025-2:2004-11		
otoriodia.	el S 235 J2		0025-2:2004-11		
All 🚽 🖬 Ste	el S 275 JR	💽 EN 1	0025-2:2004-11		
Ste	el S 275 J0	💿 EN 1	0025-2:2004-11		
Ste	el S 275 J2	💽 EN 1	0025-2:2004-11		
Ste	el S 355 JR	💿 EN 1	0025-2:2004-11		
Ste	el S 355 J0	O EN 1	0025-2:2004-11		
🗌 Include invalid 🛛 🔤 Ste	el S 355 J2	I FN 1	0025-2:2004-11		
					_
🗖 Favorites only 📴 🎦	2				7
Material Properties		S	teel S 235   EN 1	0025-2:200	04
Main Properties					
Modulus of Elasticity		E	210000.0		
- Shear Modulus		G	80769.2	N/mm <sup>2</sup>	
Poisson's Ratio		ν	0.300		
Specific Weight		γ		kN/m <sup>3</sup>	
Coefficient of Thermal Expansion		α	1.2000E-05	1/K	
Additional Properties Coefficient for Limiting Stresses of Welds			0.050	1	_
Coefficient for Limiting Stresses of Welds Correlation Factor for Fillet Welds		α <sub>w</sub> Bw	0.950		_
□ Thickness Range t ≤ 1.60 cm		Pw	0.800		-
Yield Strength		fy	235.0	N/mm <sup>2</sup>	-
Ultimate Strength		fu		N/mm <sup>2</sup>	-
Thickness Range t > 1.60 cm and t $\leq$ 4.0	0 cm		000.0		-
Yield Strength		fy		N/mm <sup>2</sup>	
Ultimate Strength		fu	360.0	N/mm <sup>2</sup>	
☐ Thickness Range t > 4.00 cm and t ≤ 10.	.00 cm				
		fv	215.0	N/mm <sup>2</sup>	
Yield Strength Ultimate Strength		Fu		N/mm <sup>2</sup>	

Figure 2.5: Dialog box Material Library

In the *Filter* section, *Steel* is preset as the material category. Select the relevant steel grade for design in the *Material to Select* list. You can check the corresponding properties in the section below.

OK

To transfer the selected material to Window 1.2 of RF-STEEL Plastic, click [OK] or [ $\downarrow$ ].

Chapter 4.3 of the RFEM manual describes how to filter, add, or rearrange materials.



### 2.3 Cross-Sections

This window manages the cross-sections that are used for the design. In addition, you can specify optimization parameters in this window.

	A	В	C			E		F	1 - HE A 400	I DIN 102	5-3:1994
	Material	Cross-Section	Cross-Sect	ion	Opti-					·	
No.	No.	Description	Туре		mize	Rem	nark	Comment		300.0	
1	1	T HE A 400	I-section	Fro	om Current Row	1 2	)		+	300.0	
2	2	IS 360/170/8/14/0	I-section	L	No				+		
3	2	T IS 500/170/8/14/0	I-section		No				0		27.0
6	1	T HE A 160	I-section	1	No						21.0
7	1	T HE A 120	I-section		No	5	)				
9	1	I IPE 360	I-section	1	No				390.0	· · · ·	
10	1	T HE A 140	I-section		No				er3		
12		🔜 🖪 QRO 80x4	Box		No					11.0	<u>)</u>
13	1	<ul> <li>RD 24</li> </ul>	Round ba		No						
15	1	T HE A 200	I-section	1	No					mille	
16		Rectangle 200/200	Invalid		No	5	)			- 1	
17	1	I IPE 360	I-section		No				_	z	
		2) The cross-section will be opt	mized, utilizing the be	est section f	from the table.			•	Cross-section	No. 1 us	(n
ross-Se	ection Prop	Derties - HEA 400		est section f				, 👔 💿	Cross-section	n No. 1 use	ă 🗗 🤇
ross-Se Cross-	ection Prop Section Ty	erties - HE A 400			I-section	(		•			ă 🗗 (
ross-Se Cross- Cross-	ection Prop Section Ty Sectional /	erties - HEA400 pe		A	I-section 159.00	( cm <sup>2</sup>			Cross-section Members No.	:	ed in
Cross-Se Cross- Cross- Effecti	ection Prop Section Ty Sectional / ive Shear /	Perties - HE A 400 pe Area		A A <sub>v.y</sub>	I-section 159.00 95.00	( cm <sup>2</sup> cm <sup>2</sup>			Cross-section	:	ed in
ross-Se Cross- Cross- Effecti Effecti	ection Prop Section Ty Sectional / ive Shear / ive Shear /	Lecties - HE A 400 pe Pe Area Area Area		A A <sub>v.y</sub> A <sub>v.z</sub>	I-section 159.00 95.00 38.63	cm <sup>2</sup> cm <sup>2</sup> cm <sup>2</sup>			Cross-section Members No. 1,2,11,12,21	,22,31,32,	ed in
ross-Se Cross- Cross- Effecti Mome	ection Prop Section Ty Sectional / ive Shear / ive Shear / nt of Inertia	Perties - HE A 400 pe Prea Area Area a		A Av.y Av.z Iy	I-section 159.00 95.00 38.63 45070.00	cm <sup>2</sup> cm <sup>2</sup> cm <sup>2</sup> cm <sup>4</sup>			Cross-section Members No. 1,2,11,12,21 Sets of memb	,22,31,32,	ed in
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Figure 2.6: Window 1.3 Cross-Sections

#### **Cross-Section Description**

The cross-sections defined in RFEM are preset together with the assigned material numbers.



To change a cross-section, click the entry in column B, thus selecting this box. To open the cross-section table of the current cross-section box, click [Cross-Section Library] or [...] in the box or press the function key [F7] (see the following figure).

In this dialog box, you can select a different cross-section or a different cross-section table. To select a different cross-section category, click [Back to cross-section library]. The general cross-section library opens.

Chapter 4.13 of the RFEM manual describes how to select cross-sections from the library.

<del>/ ``</del> Dlubal

Thin-Walled Cross-Sections - Sym	metric I-Section		×
Cross-Section Type $\begin{bmatrix} I & I & I & T \\ T & L & L \\ \hline T & L & L \\ \hline T & T & T \\ \hline T & T $	Second system         h:       360.0 \$\sqrt{b}\$ [mm]         b:       170.0 \$\sqrt{b}\$ [mm]         s:       8.0 \$\sqrt{b}\$ [mm]         t:       14.0 \$\sqrt{b}\$ [mm]         a:       0.0 \$\sqrt{b}\$ [mm]		
Favorites Group BS Figure Participation Part	<b>N</b>	IS 360/170/18/14/0	
2 🔤 🖻 😭			OK Cancel

Figure 2.7: IS cross-sections in the cross-section library

You can also enter the new cross-section description in the cross-section box directly. If the data base contains the entry, RF-STEEL Plastic imports the according cross-section parameters, too.

A modified cross-section is highlighted in blue.

If cross-sections specified in RF-STEEL Plastic are different from the ones used in RFEM, both cross-sections are displayed in the graphic on the right. The designs are carried out with the internal forces from RFEM for the cross-section selected in RF-STEEL Plastic.

#### **Cross-Section Type**

The cross-section type is decisive for the design method (see Chapter 3.2, page 18):

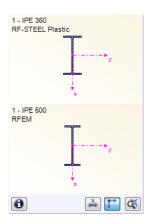
- Cross-sections consisting of three or two plates (I-, C-, Z-, L-sections, channels, tees), flat steel, pipes, and hollow sections: Partial Internal Forces Method with redistribution by KINDMANN/FRICKEL
- Elliptical cross-sections: analytical nonlinear optimization method
- General cross-sections: Simplex Method.

#### Max. Design Ratio

This table column is displayed only after the calculation. It serves as a decision support for the optimization. By means of the design ratio and colored relation scales, you can see which cross-sections are little utilized and thus oversized, or overstressed and thus undersized.

#### Optimize

Each allowable cross-section can undergo an optimization process. For the RFEM internal forces, the program searches the cross-section that comes as close as possible to a user-defined maximum design ratio. This ratio can be specified in the *General* tab of the *Details* dialog box (see Figure 3.2, page 17).





To optimize a cross section, open the drop-down list in column D or E and select the relevant entry: *From current row* or, if available, *From favorites 'Description'*. Recommendations for the cross-section optimization can be found in Chapter 7.2, page 40.

#### Remark

0

0

This column shows remarks in the form of footers that are described in detail below the crosssection list.

A warning might appear before the calculation: *Incorrect type of cross-section No. XX*. This means that there is a cross-section that is not registered in the data base. This can be a user-defined cross-section or a SHAPE-THIN cross-section that has not been calculated yet. To select an appropriate cross-section for design, click [Library] (see description after Figure 2.6).

#### Member with Tapered Cross-Section

For tapered members with different cross-sections at the start and end, the module displays both cross-section numbers in two rows, in accordance with the definition in RFEM.

RF-STEEL Plastic also designs tapered members, provided that the cross-section at the start of the member has the same number of stress points as the cross-section at the end of the member. For example, the normal stresses are determined from the moments of inertia and the distances of the stress points from the center of gravity. If the cross-sections at the start and the end of a tapered member have a different number of stress points, the intermediate values cannot be interpolated. The calculation is possible neither in RFEM nor in RF-STEEL Plastic.

The cross-section's stress points including numbering can also be checked graphically. To do this, select the cross-section in Window 1.3, and then click [Info]. The dialog box shown in Figure 2.8 appears.

#### Info About Cross-Section

In the *Info About Cross-Section* dialog box, you can view the cross-section properties, stress points, and c/t-parts.

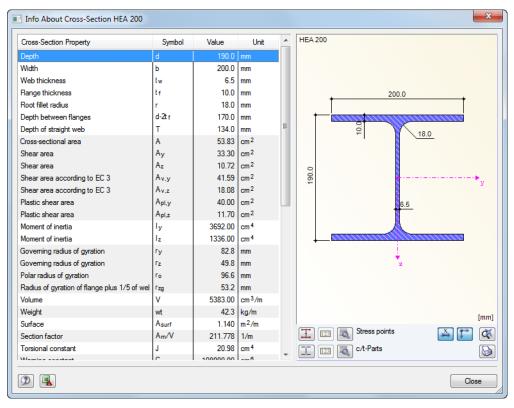


Figure 2.8: Dialog box Info About Cross-Section



The right part of the dialog box shows a graphic of the currently selected cross-section.

The buttons below the graphic have the following functions:

Button	Function
Ŧ	Displays or hides the stress points
	Displays or hides the c/t-parts
123	Displays or hides the numbers of stress points or c/t-parts
	Displays or hides details of the stress points or c/t-parts (see Figure 2.9)
X	Displays or hides the dimensions of the cross-section
\$⇒	Displays or hides the main axes of the cross-section
X	Resets the full view of the cross-section graphic

Table 2.2: Buttons of the cross-section graphic

Q

By means of the [Details] button, you can call up detailed information on stress points (distances to center of gravity, statical moments of area, normalized warping constants, etc.) and c/t-parts.

	А	B	C	D	E	F	G	HEA 200
tressP	Coordir	nates	Statical Mom	ents of Area	Thickness	Warp	ing	
No.	y [mm]	z [mm]	Qy [cm <sup>3</sup> ]	Q <sub>z</sub> [cm <sup>3</sup> ]	t [mm]	W <sub>no</sub> [cm <sup>2</sup> ]	Sw [cm <sup>4</sup> ]	
1	-100.0	-95.0	0.00	0.00	10.0	90.00	0.00	
2	-21.3	-95.0	-70.69	-47.72	10.0	19.13	-429.68	
3	0.0	-95.0	-91.89	-50.30	10.0	0.00	-450.00	
4	21.3	-95.0	-70.69	47.72	10.0	-19.13	429.68	1 2 3 4 5
5	100.0	-95.0	0.00	0.00	10.0	-90.00	0.00	
6	-100.0	95.0	0.00	0.00	10.0	-90.00	0.00	Y'
7	-21.3	95.0	-70.88	47.74	10.0	-19.13	-429.68	
8	0.0	95.0	-91.89	50.30	10.0	0.00	-450.00	
9	21.3	95.0	-70.88	-47.74	10.0	19.13	429.68	13 y
10	100.0	95.0	0.00	0.00	10.0	90.00	0.00	
11	0.0	-67.0	-199.60	0.00	6.5	0.00	0.00	
12	0.0	67.0	-200.06	0.00	6.5	0.00	0.00	annun hannun
13	0.0	0.0	-214.19	0.00	6.5	0.00	0.00	6 7 8 9 10
								*
								A 🚺 🤇

Figure 2.9: Dialog box Stress Points of HEA 200



# 3. Calculation

### 3.1 Detail Settings

Calculation

ing dialog box, use the [Details] button available in every window of the add-on module.
 The *Details* dialog box contains the following tabs:

- Settings
- General
- Used Literature.

### 3.1.1 Settings

etails	Σ
Settings General Used Literature	
Partial Factor	
◎ Define	
77M :	
Import from Table '1.2 Materials'	
Calculation Options	
Use SHAPE-THIN for calculation of all supported cross-section types (Simplex Method)	
closs-section types (aimplex method)	
2 🐻 💽 🖪	OK Cancel

Before starting the [Calculation], you should check the design details. To open the correspond-

Figure 3.1: Dialog box Details, tab Settings

#### **Partial Safety Factor**

For the determination of the resistances  $R_d$ , the partial safety factor  $\gamma_M$  of the material is usually to be considered. If you *Define* this factor manually, it is applied globally for all materials of the design case. By default, however, the partial safety factors are taken separately for each material from the properties defined in the 1.2 *Materials* window.

#### **Calculation Options**

Cross-sections consisting of two or three plates (I-, C-, Z-, L-sections, channels, tees) are calculated according to the PIFM with redistribution according to [1], elliptical cross-sections according to the non-linear optimization method. By selecting the check box, you can calculate these cross-section types also according to the Simplex Method (see Chapter 3.2), which is usually used only for general cross-sections.



#### 3.1.2 General

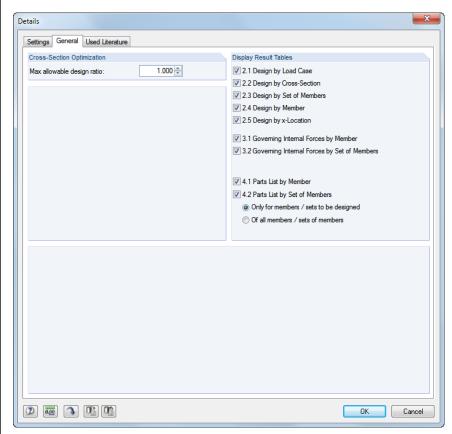


Figure 3.2: Dialog box Details, tab General

#### **Cross-Section Optimization**

The optimization is targeted on the maximum design ratio of 100 %. If necessary, you can also specify a different upper limit in the text box.

#### **Display Result Tables**

Here, you can select which results windows and parts list you want to display. These windows are described in Chapter 4 *Results*.



### 3.2 Design Methods

Depending on the cross-section type, one of the following methods is used.

#### Partial Internal Forces Method (PIFM)

According to the PIFM with redistribution by KINDMANN/FRICKEL [1], you can design cross-sections consisting of two or three plates: top flange, web and, if available, bottom flange. The flanges must be arranged horizontally, the web vertically. In this way, the most frequently used cross-sections are considered.

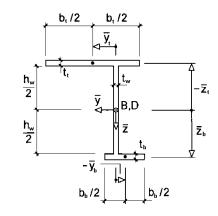


Figure 3.3: General cross-section consisting of three plates (horizontal-vertical-horizontal)

If the top or bottom flange is left out, you can consider cross-sections consisting of two plates like tees or L-sections.

The method by KINDMANN/FRICKEL allows you to design flat steel sections, pipes, and hollow sections. The calculation methods are described in [1], Chapter 10.



In Chapter 8 of this manual, you find worked examples for various sections analyzed according to the PIFM.

#### Plastic interaction relations for elliptical cross-sections

The plastic interaction relations for elliptical cross-sections according to NOWZARTASH/MOHAREB are described in [2]. An analytical nonlinear optimization method is used to analyze the plastic capacity of elliptical hollow sections.

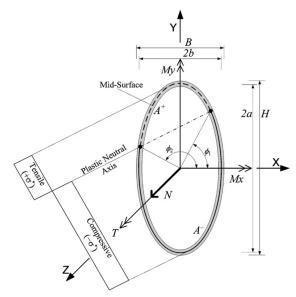


Figure 3.4: Elliptical hollow sections with interaction from axial force, torsion, and double bending according to [2]



#### **Simplex Method**

For a linear optimization problem, the cross-section is discretized into a finite number of surface elements that are as small as possible. If all internal forces of an x-location are consistently multiplied by a factor, the plastic capacity is found for a certain value. A combination of internal forces can be described by means of the following vector:

 $F = \{N, M_u, M_v, V_u, V_v, M_T\}$ 

In the calculation of the plastic resistance, a constant ratio of the components is assumed in this vector, so that the factor enlarges the internal force vector *F* up until the yield area. The factor is determined as the maximum of a linear optimization problem using a revised simplex algorithm. With the yield conditions according to VON MISES, we obtain a coordinate plane of normal and shear stresses of an ellipse which is approximated by an inscribed octagon.

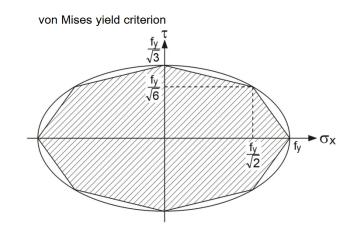


Figure 3.5: Linear approximation of the yield criterion

With this method, you can analyze general cross-sections with thin-walled element thicknesses. They are also used in the cross-section program SHAPE-THIN (see [3]).

The *Details* dialog box allows you to calculate the cross-sections consisting of two or three plates and hollow sections according to the Simplex Method (see Figure 3.1, page 16).

Details...



#### Start Calculation 3.3

Calculation

To start the calculation in RF-STEEL Plastic, use the [Calculation] button available in every input window of the module.

RF-STEEL Plastic searches for the results of the load cases, load combinations, and result combinations selected for design. If no results can be found, the program starts the RFEM calculation to determine the design-relevant internal forces.

You can also start the calculation in the RFEM user interface. To do this, use the To Calculate dialog box (menu Calculation  $\rightarrow$  To Calculate), containing design cases as well as load cases or load combinations.

lot Calculate	d			Selected for	Calculation
No.	Description	*		No.	Description
Qi LC9	Imperfection towards -X			CA1	STEEL Plastic - Design of steel members according to Partial I
Qi LC10	Imperfection towards +Y				
C01	Swt+s+wx+p+lmp				
CO2	Swt+s+Imp				
CO3	Swt+wx+Imp				
CO4	Swt+p+Imp				
CO5	Swt+Wind lifting+Imp		_		
CO6	Swt+wy+Imp		>		
C07	Swt+w(-y)+Imp		>>		
CO8	Swt+s+wy+p+lmp				
CO9	Swt+s+w(-y)+p+lmp				
CO11	Swt+s+wx+p+lmp (char. values)				
CO12	Swt+p+Imp (char. values)		4		
CO13	Swt+s+wx+lmp (char. values)	=	_		
CO14	Swt+p+Imp (char. values)	-			
CO15	Swt+Wind lifting+Imp (char.values)				
CO16	Swt+wy+lmp (char. values)				
C017	Swt+w(-y)+Imp (char. values)				
CO18	Swt+s+wy+p+lmp (char. values)				
CO19	Swt+s+w(-y)+p+lmp (char. values)				
RC1	Extreme design values				
RC2	Extreme characteristic values				
CA1	RF-STEEL Members - General stress analysis of steel memb	ers 📃			
		*			
AI	<b>▼</b>	a			

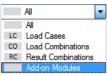


Figure 3.6: Dialog box To Calculate

If the RF-STEEL Plastic cases are missing in the Not Calculated list, select All or Add-on Modules in the drop-down list at the end of the dialog box section.

To transfer the selected RF-STEEL Plastic case to the section on the right, click [▶]. Click [OK] to start the calculation.

Alternatively, you can start the calculation of a design case by using the drop-down in the toolbar. In this list, select the RF-STEEL Plastic case, and then click [Show Results].

Add-on Modules Window	Help
	n of steel members according to Partial Internal 🝸 <> 🔎 🌋 餐 🚟 🕷 📾
웹 - 1 🐎 - 🎙 🍇 🍇 🖲	🖥 🖏 - 🛙 🧏 🥰 🥰 🖾 🗗   🕅 🛱 🍀 🏹 🛱 - 🛂 -   🎯 - 🥵 Show Results 🔊 🦉

Figure 3.7: Direct calculation of an RF-STEEL Plastic case in RFEM

Subsequently, you can observe the design process in a separate dialog box.



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#### **Results** 4.

Immediately after the calculation, the 2.1 Design by Load Case window is shown.

A1 - Design of steel members 🔻	2.1 Desigr	n by Load Case											
put Data		A	В	C	D	E				F			
- General Data	Load-		Member	Location	Design								
Materials	ing	Description	No.	x [m]	Ratio				Design	n According to	Formula		
Cross-Sections		Ultimate Limit State Design											
sults	LC1	Self-weight	67	3.125			108) Check of t						
Design by Load Case	LC2	Snow	23	0.000			108) Check of t						
Design by Cross-Section	LC3	Side wind in X	51	0.000			108) Check of t			e bending mom	ent about the r	najor axis	
Design by Member	LC4	Wind on gable Y	122	0.000			118) Check of a						
Design by x-Location	LC5	Wind on gablel in -Y	121	0.000			118) Check of a						
Governing Internal Forces by №	LC6	Wind lifting	13	0.000			108) Check of t						
Parts List by Member	LC7	Live load on ridge	66	3.125	0.87	/ ≤1	108) Check of t	he minimu	m allowable	e bending mom	ent about the r	najor axis	
				Max:	0.97	<1	<b>A</b>			3 <b>E</b>	> 1.0 -	7 😂 🛐	
				max.	0.07	121	•				21.0		
		Member 67 - x: 3.125 m - LC1	N 10000-10	00.11							9 - IPE 20	00	
	🕀 Materi	ial Properties - Steel S 355   DI	N 18800:19	90-11									
		-Section Properties - IPE 200											
		n Internal Forces											
	🖃 Desig											. 100.0	
		sign axial force in cross-section			N		63.907					+	
		sign bending moment in cross-s	section abou	ıt major axis	My		55.887				_ +		
		wable axial force in web			N lim,		350.967					8 12.0	
		nimum allowable axial force in to				min, fo							_
		ximum allowable axial force in t				max,fo							
		nimum allowable axial force in b				min, fu	-278.182				200.0		
		ximum allowable axial force in b				max,fu							
		nimum allowable axial force in c			N lim,		-907.331					5.6	
		ximum allowable axial force in o			N lim,		907.331					1	
		nimum allowable bending mome			My,r		-69.517	kNm		[1]: Tab. 10	<u>e</u>    +	anathan	
	Rat	tio of design bending moment a	about major a	axis to minimum allo	wat My/	My, min	0.80		≤ 1.000				
												z	
	_										_		
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Figure 4.1: Results window with designs and intermediate values

The designs are shown in the results windows 2.1 through 2.5, sorted by different criteria.

Windows 3.1 and 3.2 show the governing internal forces. Windows 4.1 and 4.2 show the parts lists by members and sets of members.

OK

To open a window, click the corresponding entry in the navigator. To go to the previous or next input window, use the buttons shown on the left. Alternatively, you can use the function keys to go the next [F2] or previous [F3] window.

Click [OK] to save the results. Thus you exit RF-STEEL Plastic and return to the main program.

Chapter 4 Results describes the different results windows one by one. Chapter 5 Evaluation describes evaluating and checking results, page 30 f.



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FIVYIAIII KESILLE FIASUL®	2014 Diubai Soltwale Gilibii



### 4.1 Design by Load Case

The upper part of the window shows a summary of the governing checks sorted by load case, load combination, and result combination.

The lower part provides detailed information about the cross-section properties, design internal forces, and check parameters for the load case selected above.

	A	В	C	D	E				F							0
Load-		Member	Location	Design												_
ing	Description	No.	x [m]	Ratio				Desigr	n According to	o Formula						D
	Ultimate Limit State Design															
LC1	Self-weight	67	3.125	0.8	0 ≤1	108) Check of t	he minimi	um allowable	bending mor	nent about	the ma	ajor ax	dis			
LC2	Snow	23	0.000	0.5	1 ≤1	108) Check of t	he minimi	um allowable	bending mor	nent about	the ma	ajor ax	dis			
LC3	Side wind in X	51	0.000	0.1	7 ≤1	108) Check of t	he minimi	um allowable	bending mor	nent about	the ma	ajor ax	dis			
LC4	Wind on gable Y	122	0.000	0.4	1 ≤1	118) Check of a	ixial plast	ic capacity								
LC5	Wind on gablel in -Y	121	0.000			118) Check of a										
LC6	Wind lifting	13	0.000	0.2	0 ≤1	108) Check of t	he minim	um allowable	bending mor	nent about	the ma	ajor ax	dis			
LC7	Live load on ridge	66	3.125	0.8	7 ≤1	108) Check of t	he minimi	um allowable	bending mor	nent about	the ma	ajor ax	dis			
			Max:	0.8	87 ≤ 1	9			<b>*</b>	> 1,0	•	7	2			
] Desig	n Internal Forces n Ratio sign axial force in cross-secti			N		63.907	LN		1	_			100.0			
	sign axial force in cross-secti sign bending moment in cros		t maior avie	Mv		55.887				-		Ι.				
	owable axial force in web	0 0000011 0000	e major asta	Nlin		350.967				-		8.5 8.5	W			
	nimum allowable axial force in	top flange			n, min, fo			-		-		80		12	0	
	aximum allowable axial force in				n.max.fo					-						
	nimum allowable axial force in				n, min, fu			-		-	200.0					
	ximum allowable axial force in				n.max.fu					-	2(					1
— Ma	nimum allowable axial force in	cross-section		Nim	n,min	-907.331							5.	.6		
	ximum allowable axial force in	n cross-section	I		n,max	907.331		-	1	-						
Mir	aximum allowable axial force in								[ FA1 TT 1 40				do a	1111		
Mir Ma	ximum allowable axial force ii nimum allowable bending mor	ment about loc	al major axis	My.	min	-69.517	KINM		[1] : Tab. 10	J.	- +					
Mir Ma Mir							kNm	≤ 1.000	[1]:1ab.10		+		1			
Mir Ma Mir	nimum allowable bending mor						kNm	≤ 1.000	[I]: Iab. IU	<u>.</u>	+		+ z			
Mir Ma Mir	nimum allowable bending mor						kinim	≤ 1.000	[I]: Iab. IU		+		ż			
Mir Ma Mir	nimum allowable bending mor						KNM	≤ 1.000		<u>).</u> 	+		z			
Mir Ma Mir	nimum allowable bending mor						KNM	≤ 1.000		<u>.</u>	+		z			
Mir Ma Mir	nimum allowable bending mor						KNM	≤ 1.000		J	+		* 2			ſm

Figure 4.2: Window 2.1 Design by Load Case

#### Description

This column shows the descriptions of the load cases, load combinations, and result combinations used for the designs.

#### Member No.

This column shows the number of the member with the maximum design ratio of the analyzed loading.

#### Location x

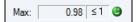
This column shows the corresponding x-location where the member's maximum design ratio occurs. For the table output, the program uses the following member locations *x*:

- Start and end node
- Division points according to possibly defined member division (see RFEM Table 1.16)
- Member division according to specification for member results (RFEM dialog box *Calculation Parameters*, tab *Global Calculation Parameters*)
- Extreme values of the internal forces.

#### Design

Columns D and E show the design conditions

The length of the color scale represents the respective stress ratio.





#### **Design According to Formula**

This column shows the equations of the standard used in the checks.

### 4.2 Design by Cross-Section

	A	B	С	D		Е					F				
Section	Member	Location	Load	D	esign										
No.	No.	x [m]	Case	Rati	io					Des	ign Accordi	ng to Formula			
1	HEA 360														
	1	6.000	LC4		0.00	≤1	101) C	heck of shear fl	ow in top flang	je					
	32	0.000	LC2		0.20	≤1	102) C	heck of shear fl	ow in web	-					
	1	6.000	LC4		0.00	≤1	103) C	heck of shear fl	ow in bottom f	lange					
	1	3.000	LC4		0.03	≤1	104) C	heck of the allo	wable bending	moment in	n top flange				
	1	3.000	LC4		0.03	≤1	105) C	heck of the allo	wable bending	) moment ir	h bottom flar	nge			
	31	0.000	LC1		0.04	≤1	106) C	heck of the min	mum allowabl	e axial force	e acting on	cross-section			
	31	0.000	LC1		0.04	≤1	107) C	heck of the ma	imum allowab	le axial forc	e acting on	cross-section			
	21	6.000	LC2					heck of the min							
	21	6.000	LC2		0.41	≤1	109) C	heck of the ma	imum allowab	le bending	moment ab	out the major a	xis		
			Max:		0.87	≤1	۲					🅦 🗾 🛛	> 1,0	• 7	😂 属 🗞
	n Internal F n Ratio	orces											-		
Desig	n Ratio												-		. 0.0
		of top flange						fy,fo		kN/cm <sup>2</sup>				+ <u></u>	1
		of top flange						fy.t.fo		kN/cm <sup>2</sup>			+		
		ulus of top fla						IT,fo	51.62					7.5	27.0
		nal moment wi						Tprim		kNm				-1	21.0
		sional momen			center			Tsec	0.000						
		top flange in						V <sub>y,fo</sub>	1.877				350.0		
		capacity of top		local y-dire	ection			V <sub>pl,y,fo</sub>	661.329						
		nal moment in						Tprim, fo	0.006						10.0
		al capacity of	top flange					T <sub>pl,fo</sub>	5.618						<u> </u>
- Pla		top flange				0		Tfo		kN/cm <sup>2</sup>	< 1.000		+		
Pla She		stress in top	tiange to yi	eia strengt	n or top	tiang	je	τ <sub>fo</sub> /f <sub>y.τ.fo</sub>	0.00		≤ 1.000		-		÷
Pla She	tio of shear												-		z
Pla She	tio of shear												-		
Pla She	tio of shear														
Pla She	tio of shear												-		
Pla She	tio of shear												-		
Pla She	tio of shear												-		

Figure 4.3: Window 2.2 Design by Cross-Section

This window shows the maximum design ratios of all members and actions selected for design, sorted by cross-section.

If there is a tapered member, both cross-section descriptions are displayed in the table row next to the section number.



### 4.3 Design by Set of Members

	A	B	C	D	E	1				F						
Set	Member	Location	Load	Design												
No.	No.	x [m]	Case	Ratio					Des	ign Accord	ing to Formula					
1	1 (Membe	r No. 1,3-8,2	?)													
	1	6.000	LC4				eck of shear flo		je							
	3	3.011	LC2				eck of shear flo									
	1	6.000	LC4				eck of shearflo									
	1	3.000	LC4				eck of the allow									
	1	3.000	LC4				eck of the allov									
	1	0.000	LC1				eck of the mini									
	1	0.000	LC1				eck of the max									
	3	0.000	LC2				eck of the minii									
	3	0.000	LC2	0.25	≤1	109) Ch	eck of the max	imum allowab	le bending	moment ab	out the major	axis				
			Max:	0.87	<1	0					D 🗐	> 1,0	-	7 😂		TA I
Mate Cross	rial Propertie s-Section Pr	- x: 6.000 m es - Steel S 2 operties - H	35   DIN 18	800:1990-11								1-+	IEA 360			
Mate Cross Desig Desig	rial Propertie s-Section Pr gn Internal P gn Ratio	es - Steel S 2 operties - H orces	35   DIN 18 EA 360	800:1990-11			fy fo	21.82	kN/cm <sup>2</sup>			1-+	IEA 360	300.0		
Mate Cross Desig Desig Yie	rial Propertie s-Section Pri gn Internal Fi gn Ratio eld strength	es - Steel S 2 operties - H	35   DIN 18 EA 360	800:1990-11			f <sub>y,fo</sub> f <sub>y,т,fo</sub>		kN/cm <sup>2</sup> kN/cm <sup>2</sup>			1-+	IEA 360	300.0		
Mate Cross Desig Desig Yie Yie	rial Propertie s-Section Pr gn Internal F gn Ratio eld strength eld strength	es - Steel S 2 operties - H forces of top flange	35   DIN 18 EA 360 in shear	800:1990-11			fy.fo fy.т.fo IT.fo		kN/cm <sup>2</sup>			1-F	IEA 360	300.0		
Mate Cross Desig Desig Yie Yie To	rial Propertie s-Section Pro gn Internal P gn Ratio eld strength eld strength prsional mod	es - Steel S 2 operties - H orces of top flange of top flange ulus of top fla	35   DIN 18 EA 360 in shear	800:1990-11			fy.t.fo	12.60	kN/cm <sup>2</sup> cm <sup>4</sup>			1 - F	IEA 360	300.0	27.0	
Mate Cross Desig Desig Yie Yie To Pri	rial Propertie s-Section Pr gn Internal F gn Ratio eld strength eld strength risional mod imary torsion econdary tors	es - Steel S 2 operties - H orces of top flange of top flange ulus of top fla al moment w sional momer	35   DIN 18 EA 360 in shear ange ith respect t	to web center ect to web center			f <sub>y,τ,fo</sub> I <sub>T,fo</sub> T <sub>prim</sub> T <sub>sec</sub>	12.60 51.62 0.018 0.000	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm				1EA 360	300.0	27.0	
Mate Cross Desig Disig Yie Yie To Pri Se Sh	rial Propertie s-Section Pr gn Internal F gn Ratio eld strength eld strength visional mod imary torsion econdary tor- near force in	es - Steel S 2 operties - H forces of top flange of top flange ulus of top fla al moment w sional momer top flange in	35   DIN 18 EA 360 in shear ange ith respect t at with respect local y-dire	to web center ect to web center ction			F <sub>y,τ,fo</sub> I <sub>T,fo</sub> T <sub>prim</sub> T <sub>sec</sub> V <sub>y,fo</sub>	12.60 51.62 0.018 0.000 1.877	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN				IEA 360	300.0	27.0	
Mate Cross Desig Desig Yie Yie To Pri Se Sh	rial Propertie s-Section Pro- gn Internal F gn Ratio eld strength deld strength provident	es - Steel S 2 operties - H forces of top flange of top flange ulus of top flange ulus of top flange in moment w sional moment top flange in capacity of to	35   DIN 18 EA 360 in shear ange ith respect t nt with respect local y-dire p flange in l	to web center ect to web center			fy.τ.fo           IT.fo           Tprim           Tsec           Vy.fo           Vpl.y.fo	12.60 51.62 0.018 0.000 1.877 661.329	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kN			1-+ 0.055	IEA 360			
Mate Cross Desig Desig Yie Yie To Pri Se Sh Pla	rial Propertie s-Section Pro- gn Internal F gn Ratio eld strength del strength provident	es - Steel S 2 operties - H orces of top flange of top flange ulus of top fla al moment w sional moment top flange in apacity of to al moment in	35   DIN 18 EA 360 in shear ange ith respect t nt with respect local y-dire p flange in l top flange	to web center ect to web center ction			fy.τ.fo           IT.fo           Tprim           Tsec           Vy.fo           Vpl,y.fo           Tprim,fo	12.60 51.62 0.018 0.000 1.877 661.329 0.006	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kN kN				1EA 360		27.0	-
Mate Cross Desig Desig Yie Yie Yie Se Sh Pri Se Sh Pla Pla	rial Propertie s-Section Pri gn Internal F gn Ratio eld strength eld strength brsional mod imary torsion acondary tor ear force in astic shear o imary torsion astic torsion	es - Steel S 2 operties - H orces of top flange of top flange ulus of top fla al moment w sional momer top flange in apacity of to al moment in al capacity of	35   DIN 18 EA 360 in shear ange ith respect t nt with respect local y-dire p flange in l top flange	to web center ect to web center ction			fy.τ.,fo           IT,fo           Tprim           Tsec           Vy,fo           Vpl,y,fo           Tprim,fo           Tpl,fo	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kN kNm kNm				1EA 360			
Mate Cross Desig Desig Yit To Prio Se Sh Pla Pla Sh	rial Propertie s-Section Pri gn Internal F gn Ratio eld strength eld strength risional mod imary torsion econdary tor iear force in astic shear c imary torsion astic torsion mear stress in	es - Steel S 2 operties - H orces of top flange of top flange ulus of top fla al moment w sional momert top flange in capacity of to al moment in al capacity of top flange	35   DIN 18 EA 360 in shear ange ith respect to t with respect local y-dire p flange in I top flange top flange	to web center act to web center ction local y-direction			Γy, τ, fo           IT, fo           Tprim           T sec           Vy, fo           Vpl, y, fo           Tprim, fo           Tpl, fo           Tpl, fo           To	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618 0.04	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kNm kNm kNm kN/cm <sup>2</sup>				1EA 360			
Mate Cross Desig Desig Yit To Prio Se Sh Pla Pla Sh	rial Propertie s-Section Pri gn Internal F gn Ratio eld strength eld strength risional mod imary torsion econdary tor iear force in astic shear c imary torsion astic torsion mear stress in	es - Steel S 2 operties - H orces of top flange of top flange ulus of top fla al moment w sional momert top flange in capacity of to al moment in al capacity of top flange	35   DIN 18 EA 360 in shear ange ith respect to t with respect local y-dire p flange in I top flange top flange	to web center ect to web center ction			fy.τ.,fo           IT,fo           Tprim           Tsec           Vy,fo           Vpl,y,fo           Tprim,fo           Tpl,fo	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kNm kNm kNm kN/cm <sup>2</sup>	≤ 1.000			IEA 360			
Mate Cross Desig Desig Yit To Prio Se Sh Pla Pla Sh	rial Propertie s-Section Pri gn Internal F gn Ratio eld strength eld strength risional mod imary torsion econdary tor iear force in astic shear c imary torsion astic torsion mear stress in	es - Steel S 2 operties - H orces of top flange of top flange ulus of top fla al moment w sional momert top flange in capacity of to al moment in al capacity of top flange	35   DIN 18 EA 360 in shear ange ith respect to t with respect local y-dire p flange in I top flange top flange	to web center act to web center ction local y-direction			Γy, τ, fo           IT, fo           Tprim           T sec           Vy, fo           Vpl, y, fo           Tprim, fo           Tpl, fo           Tpl, fo           To	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618 0.04	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kNm kNm kNm kN/cm <sup>2</sup>	≤ 1.000			1EA 360			
Mate Cross Desig Desig Yit To Prio Se Sh Pla Pla Sh	rial Propertie s-Section Pri gn Internal F gn Ratio eld strength eld strength risional mod imary torsion econdary tor iear force in astic shear c imary torsion astic torsion mear stress in	es - Steel S 2 operties - H orces of top flange of top flange ulus of top fla al moment w sional momert top flange in capacity of to al moment in al capacity of top flange	35   DIN 18 EA 360 in shear ange ith respect to t with respect local y-dire p flange in I top flange top flange	to web center act to web center ction local y-direction			Γy, τ, fo           IT, fo           Tprim           T sec           Vy, fo           Vpl, y, fo           Tprim, fo           Tpl, fo           Tpl, fo           To	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618 0.04	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kNm kNm kNm kN/cm <sup>2</sup>	≤ 1.000			1EA 360			
Mate Cross Desig Desig Yit To Prio Se Sh Pla Pla Sh	rial Propertie s-Section Pri gn Internal F gn Ratio eld strength eld strength risional mod imary torsion econdary tor iear force in astic shear c imary torsion astic torsion mear stress in	es - Steel S 2 operties - H orces of top flange of top flange ulus of top fla al moment w sional momert top flange in capacity of to al moment in al capacity of top flange	35   DIN 18 EA 360 in shear ange ith respect to t with respect local y-dire p flange in I top flange top flange	to web center act to web center ction local y-direction			Γy, τ, fo           IT, fo           Tprim           T sec           Vy, fo           Vpl, y, fo           Tprim, fo           Tpl, fo           Tpl, fo           To	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618 0.04	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kNm kNm kNm kN/cm <sup>2</sup>	≤ 1.000			1EA 360			
Mate Cross Desig Desig Yit To Prio Se Sh Pla Pla Sh	rial Propertie s-Section Pri gn Internal F gn Ratio eld strength eld strength risional mod imary torsion econdary tor iear force in astic shear c imary torsion astic torsion mear stress in	es - Steel S 2 operties - H orces of top flange of top flange ulus of top fla al moment w sional momert top flange in capacity of to al moment in al capacity of top flange	35   DIN 18 EA 360 in shear ange ith respect to t with respect local y-dire p flange in I top flange top flange	to web center act to web center ction local y-direction			Γy, τ, fo           IT, fo           Tprim           T sec           Vy, fo           Vpl, y, fo           Tprim, fo           Tpl, fo           Tpl, fo           To	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618 0.04	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kNm kNm kNm kN/cm <sup>2</sup>	≤ 1.000			1EA 360			

Figure 4.4: Window 2.3 Design by Set of Members

This results window is displayed if you have selected at least one set of members for design. The window lists the maximum design ratios sorted by set of members.

The *Member No*. column shows the number of the one member within the set of members that bears the maximum ratio for the respective design criterion.

The output by set of members allows you to clearly present the design for an entire structural group (for example, a frame).



### 4.4 Design by Member

	A	B	С	D					E							
Member	Location	Load	Design													
No.	x [m]	Case	Ratio					Design A	ccording to	Formula						
1	Cross-section	n No. 1 - H														
	6.000	LC4				eck of shear flow in to										
	0.000	LC2				eck of shear flow in w										
	6.000	LC4				eck of shear flow in b										
	3.000	LC4				eck of the allowable b										
	3.000	LC4				eck of the allowable b										
	0.000	LC1				eck of the minimum al										
	0.000	LC1				eck of the maximum a										
	6.000	LC2				eck of the minimum al										
	6.000	LC2	0.21	≤1	109) Che	eck of the maximum a	lowable bending	moment a	bout the ma	ajor axis						
		Max:	0.87	<1	()					🌮 🖺	> 1.0		• •	2		<b>A</b>
	-Section Prope n Internal Forc	erties - HE ces	A 360													
∃ Desigr ∃ Desigr	n Internal Forc n Ratio	es	A 360											300.0		
∃ Desigr ∃ Desigr Yiel	n Internal Forc n Ratio Id strength of t	ces top flange				fy,fo	21.02	kN/cm <sup>2</sup>				1		300.0		ŀ
∃ Desigr ∃ Desigr Yîel Yîel	n Internal Forc n Ratio Id strength of t Id strength of t	ces top flange top flange i	n shear			fy. t. fo	12.60	kN/cm <sup>2</sup>				+		300.0		
∃ Desigr ∃ Desigr Yiel Yiel Tor	n Internal Ford n Ratio Id strength of t Id strength of t sional modulus	ces top flange top flange in s of top flar	n shear nge			fy, τ, fo IT, fo	12.60	kN/cm <sup>2</sup> cm <sup>4</sup>				<u></u>	17.5	300.0	27.0	
Design     Design     Design     Yiel     Yiel     Yiel     Ton	n Internal Force n Ratio Id strength of t sional modulus nary torsional n	ces top flange top flange in s of top flar moment wit	n shear nge h respect to web			f <sub>y,τ,fo</sub> IT,fo Tprim	12.60 51.62 0.018	kN/cm <sup>2</sup> cm <sup>4</sup> kNm				<u></u> _†	17.5	300.0	27.0	Ì
Desigr     Desigr     Desigr     Yiel     Yiel     Yiel     Tors     Prim     Sec	n Internal Ford n Ratio Id strength of t sional modulus nary torsional n condary torsion	top flange top flange in s of top flar moment witt nal moment	n shear nge h respect to web : with respect to w			F <sub>y,τ,fo</sub> IT,fo Tprim Tsec	12.60 51.62 0.018 0.000	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm					17.5	300.0	27.0	
Design Design Yiel Yiel Ton Prim Sec She	n Internal Force n Ratio Id strength of t sional modulus nary torsional r condary torsion ar force in top	top flange top flange in s of top flar moment wit nal moment o flange in l	n shear nge h respect to web : with respect to w ocal y-direction	/eb c	enter	Γ <sub>y,τ,fo</sub> IT,fo Tprim Tsec Vy,fo	12.60 51.62 0.018 0.000 1.877	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN				350.0	17.5	300.0	. <u>27.0</u>	•,
Design Design Yiel Yiel Tors Prim Sec She Plas	n Internal Force n Ratio Id strength of t sional modulus nary torsional r condary torsior ear force in top stic shear cap	top flange top flange in s of top flar moment wit nal moment o flange in l acity of top	n shear nge h respect to web with respect to w ocal y-direction flange in local y-t	/eb c	enter	f <sub>y,τ,fo</sub> IT,fo           Tprim           Tseo           Vy,fo           Vpl,y,fo	12.60 51.62 0.018 0.000 1.877 661.329	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kN				350.0	17.5	300.0		•,
Desigr Desigr Yiel Yiel Yiel Tor Prim Sec She Plas Prim	n Internal Force n Ratio Id strength of t sional modulus nary torsional n condary torsion ear force in top stic shear cap nary torsional n	cop flange top flange in s of top flar moment witt nal moment o flange in l acity of top moment in t	n shear nge h respect to web cal y-direction flange in local y- top flange	/eb c	enter	Fy.t.fo           IT.fo           Tprim           Tsec           Vy.fo           Vpl.y.fo           Tprim.fo	12.60 51.62 0.018 0.000 1.877 661.329 0.006	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kN kN				350.0	17.5			•,
Desigr Desigr Yiel Yiel Yiel Tors Prim Sec She Plas Prim Plas	n Internal Force n Ratio Id strength of t sional modulus nary torsional r condary torsior ear force in top stic shear cap	top flange top flange in s of top flar moment witt nal moment o flange in l acity of top moment in t capacity of f	n shear nge h respect to web cal y-direction flange in local y- top flange	/eb c	enter	f <sub>y,τ,fo</sub> IT,fo           Tprim           Tseo           Vy,fo           Vpl,y,fo	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kN kN				320.0	17.5			•,
Desigr     Desigr     Desigr     Yiel     Yiel     Yiel     Yiel     Tors     Prim     Sec     She     Plas     Prim     Plas     She	n Internal Force n Ratio Id strength of t sional modulus nary torsional n condary torsion stic shear cap nary torsional n stic torsional c stic torsional c	top flange top flange in s of top flar moment with nal moment o flange in l acity of top moment in t capacity of flange	n shear nge h respect to web cal y-direction flange in local y- top flange	veb c direct	tion	Fy.τ.fo           IT, fo           Tprim           Tsec           Vy.fo           Vpl.y.fo           Tprim, fo           Tpl.fo           Tfo	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kNm kNm kNm kN/cm <sup>2</sup>	≤1.000			350.0	17.5			•, '
Desigr     Desigr     Desigr     Yiel     Yiel     Yiel     Yiel     Tors     Prim     Sec     She     Plas     Prim     Plas     She	n Internal Force n Ratio Id strength of t sional modulus nary torsional n condary torsion stic shear cap nary torsional n stic torsional c stic torsional c	top flange top flange in s of top flar moment with nal moment o flange in l acity of top moment in t capacity of flange	n shear nge h respect to web with respect to w ocal y-direction flange in local y-t rop flange top flange	veb c direct	tion	Fy.τ.fo           IT, fo           Tprim           Tsec           Vy.fo           Vpl.y.fo           Tprim, fo           Tpl.fo           Tfo	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618 0.04	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kNm kNm kNm kN/cm <sup>2</sup>	≤ 1.000			380.0	17.5			
Desigr     Desigr     Desigr     Yiel     Yiel     Yiel     Yiel     Tors     Prim     Sec     She     Plas     Prim     Plas     She	n Internal Force n Ratio Id strength of t sional modulus nary torsional n condary torsion stic shear cap nary torsional n stic torsional c stic torsional c	top flange top flange in s of top flar moment with nal moment o flange in l acity of top moment in t capacity of flange	n shear nge h respect to web with respect to w ocal y-direction flange in local y-t rop flange top flange	veb c direct	tion	Fy.τ.fo           IT, fo           Tprim           Tsec           Vy.fo           Vpl.y.fo           Tprim, fo           Tpl.fo           Tfo	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618 0.04	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kNm kNm kNm kN/cm <sup>2</sup>	≤ 1.000			350.0	17.5			•,
Desigr     Desigr     Desigr     Yiel     Yiel     Yiel     Yiel     Tors     Prim     Sec     She     Plas     Prim     Plas     She	n Internal Force n Ratio Id strength of t sional modulus nary torsional n condary torsion stic shear cap nary torsional n stic torsional c stic torsional c	top flange top flange in s of top flar moment with nal moment o flange in l acity of top moment in t capacity of flange	n shear nge h respect to web with respect to w ocal y-direction flange in local y-t rop flange top flange	veb c direct	tion	Fy.τ.fo           IT, fo           Tprim           Tsec           Vy.fo           Vpl.y.fo           Tprim, fo           Tpl.fo           Tfo	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618 0.04	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kNm kNm kNm kN/cm <sup>2</sup>	≤ 1.000			380.0	17.5			
Desigr     Desigr     Desigr     Yiel     Yiel     Yiel     Yiel     Tors     Prim     Sec     She     Plas     Prim     Plas     She	n Internal Force n Ratio Id strength of t sional modulus nary torsional n condary torsion stic shear cap nary torsional n stic torsional c stic torsional c	top flange top flange in s of top flar moment with nal moment o flange in l acity of top moment in t capacity of flange	n shear nge h respect to web with respect to w ocal y-direction flange in local y-t rop flange top flange	veb c direct	tion	Fy.τ.fo           IT, fo           Tprim           Tsec           Vy.fo           Vpl.y.fo           Tprim, fo           Tpl.fo           Tfo	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618 0.04	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kNm kNm kNm kN/cm <sup>2</sup>	≤ 1.000			350.0	17.5			(m)

Figure 4.5: Window 2.4 Design by Member

This results window shows the maximum design ratios for the individual designs sorted by member number. The columns are described in detail in Chapter 4.1, page 22.

### 4.5 Design by x-Location

.5 Design	n by x-Locat	ion												
	A	B	С	D					E					
Member	Location	Load	Design											
No.	x [m]	Case	Ratio					Design A	ccording to	Formula				L
1	Cross-sectio	n No. 1 - Hi	EA 360											
	0.000	LC4			101) Check of sl		ange							
	0.000	LC2			102) Check of sl									
	0.000	LC4			103) Check of s									
	0.000	LC1			104) Check of th									
	0.000	LC1			105) Check of th									
	0.000	LC1			106) Check of th									
	0.000	LC1			107) Check of th									
	0.000	LC1			108) Check of th									
	0.000	LC1	0.00	≤1	109) Check of th	ne maximum allov	vable bending	moment at	out the ma	ijor axis				
		Max:	0.87	≤1	۲				[	🌮 🖺	> 1,0	• 7	😂 🖪	3
	Section Prop Internal For Ratio	erties - HE/ ces	5   DIN 18800:19 \ 360	100-11									300.0	
	d strength of					fy,fo		kN/cm <sup>2</sup>			_			1
	d strength of					fy.τ.fo	51.62	kN/cm <sup>2</sup>			-   †		ullinnun	(1)
	sional modulu					IT, fo	0.018				-	17.5	27.0	
			respect to web with respect to v			Tprim Tsec	0.018				-			-
			with respect to v cal v-direction	Ved Ce	enter	V <sub>v.fo</sub>	1.873				350.0			
			lange in local y-	dimoti		V y, to V pl, y, fo	661.329				35(			У
	nary torsional			uirecu	on	Tprim.fo	0.006				-		10.0	
	stic torsional o					Tpl.fo	5.618				-			
	ar stress in to		phango			Tfo		kN/cm <sup>2</sup>			-		ana dhaa	N
			inge to yield stre	nath c	of top flange	τ <sub>fo</sub> /f <sub>V.τ.fo</sub>	0.00	iere om	≤ 1.000		-   *			
						1019.010					-		z	
											_			
														(mm
											8		X	
								-						

Figure 4.6: Window 2.5 Design by x-Location



This results window lists the maxima for each member at the locations **x** resulting from the division points in RFEM:

- Start and end node
- Division points according to possibly defined member division (see RFEM Table 1.16)
- Member division according to specification for member results (RFEM dialog box *Calculation Parameters*, tab *Global Calculation Parameters*)
- Extreme values of the internal forces.

### 4.6 Governing Internal Forces by Member

3.1 Governing Internal Forces by Member

	A	B	С	D	E	F	G	Н	
lember	Location	Load-		Forces [kN]			oments [kNm]		
No.	x [m]	ing	N	Vy	Vz	MT	My	Mz	Design According to Formula
1	Cross-section	No. 1 - HE	A 360						
	6.000	LC4	0.000	3.753	0.000	0.018	0.000		101) Check of shear flow in top flange
	0.000	LC2	-23.438	0.000	-15.206	0.000	0.000		102) Check of shear flow in web
	6.000	LC4	0.000	3.753	0.000	0.018	0.000		103) Check of shear flow in bottom flange
	3.000	LC4	0.000	0.003	0.000	0.018	0.000		104) Check of the allowable bending moment in top flange
	3.000	LC4	0.000	0.003	0.000	0.018	0.000		105) Check of the allowable bending moment in bottom flange
	0.000	LC1	-71.533	0.000	-11.085	0.001	0.000		106) Check of the minimum allowable axial force acting on cro
	0.000	LC1	-71.533	0.000	-11.085	0.001	0.000		107) Check of the maximum allowable axial force acting on cr
	6.000	LC2	-23.438	0.000	-15.206	0.000	-91.236		108) Check of the minimum allowable bending moment about
	6.000	LC2	-23.438	0.000	-15.206	0.000	-91.236	0.000	109) Check of the maximum allowable bending moment about
2	Cross-section								
	6.000	LC4	0.000	3.753	0.000	-0.018	0.000		101) Check of shear flow in top flange
	0.000	LC2	-23.438	0.000	15.206	0.000	0.000		102) Check of shear flow in web
	6.000	LC4	0.000	3.753	0.000	-0.018	0.000		103) Check of shear flow in bottom flange
	3.000	LC4	0.000	0.003	0.000	-0.018	0.000		104) Check of the allowable bending moment in top flange
	3.000	LC4	0.000	0.003	0.000	-0.018	0.000		105) Check of the allowable bending moment in bottom flange
	0.000	LC1	-71.533	0.000	11.085	-0.001	0.000		106) Check of the minimum allowable axial force acting on cro
	0.000	LC1	-71.533	0.000	11.085	-0.001	0.000		107) Check of the maximum allowable axial force acting on cr
	6.000	LC2	-23.438	0.000	15.206	0.000	91.236		108) Check of the minimum allowable bending moment about
	6.000	LC2	-23.438	0.000	15.206	0.000	91.236	0.000	109) Check of the maximum allowable bending moment about
3	Courses	N- 2 IDC	E 450 2 - IPE	200					
-	3.011	LC4	0.000	-0.040	0.000	-0.017	0.000	0.100	101) Check of shear flow in top flange
_	3.011	LC2	-16.693	0.000	16.428	0.000	-33.330		102) Check of shear flow in web
_	3.011	LC2	0.000	-0.040	0.000	+0.017	0.000		103) Check of shear flow in bottom flange
	3.011	LC4	0.000	0.040	0.000	0.017	0.000		104) Check of the allowable bending moment in top flange
	3.011	LC5	0.000	0.040	0.000	0.016	0.000		105) Check of the allowable bending moment in bottom flange
	3.011	LC2	-16.693	0.040	16.428	0.000	-33.330		106) Check of the minimum allowable axial force acting on cro
	3.011	LC2 LC2	-16.693	0.000	16.428	0.000	-33.330		107) Check of the maximum allowable axial force acting on cr
_	0.000	LC2 LC2	-17.180	0.000	22.031	0.000	-91.236		108) Check of the minimum allowable axial force acting on a 108) Check of the minimum allowable bending moment about
	0.000	LC2 LC2	-17.180	0.000	22.031	0.000	-91.236		109) Check of the maximum allowable bending moment about
	0.000	202	87.100	0.000	42.001	0.000	91.230	0.000	rooy encore of the machine allowable bending moment about
4	Cross-section	No. 2 - IPE	360						
									<b>E</b> 😫 <b>B</b> 🔊

Figure 4.7: Window 3.1 Governing Internal Forces by Member

This window shows for each member the governing internal forces that result in maximum design ratios in each check.

#### Location x

This column shows the respective x-location with the member's maximum design ratio.

#### Load Case

This column displays the number of the load case, load combination, or result combination whose internal forces produce the maximum design ratio.

#### Forces / moments

For each member, this column displays the axial and shear forces as well as the torsional and bending moments resulting in the maximum design ratios in the various cross-section checks.

#### **Design According to Formula**

The final column provides information on the check types and the formulas used in the checks according to [1], [2], or [3].



### 4.7 Governing Internal Forces by Set of Members

	A	B	C	D	E	F	G	Н							
Set	Location	Load-		Forces [kN]		Mo	oments [kNm]								
No.	x [m]	ing	N	Vy	Vz	MT	My	Mz	Design According to Formula						
1	Continuous m	Continuous members 1 (Member No. 51,52)													
	0.000	LC5	0.09	3.96	0.00	0.00	0.00	5.05							
	0.000	LC3	-0.02	0.01	2.70	0.00	-3.57	0.01							
	0.000	LC5	0.09	3.96	0.00	0.00	0.00	5.05							
	0.000	LC5	0.09	3.96	0.00	0.00	0.00		104) Check of the allowable bending moment in top flange						
	0.000	LC5	0.09	3.96	0.00	0.00	0.00		105) Check of the allowable bending moment in bottom flange						
	0.000	LC1	-89.68	-0.06	0.05	0.00	-0.05		106) Check of the minimum allowable axial force acting on cro						
	0.000	LC1	-89.68	-0.06	0.05	0.00	-0.05	-0.03	107) Check of the maximum allowable axial force acting on cri						
	0.000	LC3	-0.02	0.00	1.90	0.00	-4.78	0.02							
	0.000	LC3	-0.02	0.00	1.90	0.00	-4.78	0.02	109) Check of the maximum allowable bending moment about						
2	Continuous members 2 (Member No. 13-15)														
	0.000	LC1	-23.16	-0.02	15.54	-0.01	-31.01	0.01							
	3.011	LC1	-23.15	-0.02	15.55	-0.01	-31.01	0.01							
	0.000	LC1	-23.16	-0.02	15.54	-0.01	-31.01	0.01	103) Check of shear flow in bottom flange						
	3.262	LC4	-13.90	-0.10	-1.21	0.00	0.17		104) Check of the allowable bending moment in top flange						
	3.262	LC4	-13.90	-0.10	-1.21	0.00	0.17		105) Check of the allowable bending moment in bottom flange						
	0.000	LC1	-23.16	-0.02	15.54	-0.01	-31.01		106) Check of the minimum allowable axial force acting on cro						
	0.000	LC1	-23.16	-0.02	15.54	-0.01	-31.01	0.01							
	5.791	LC1	-20.35	0.06	-0.09	0.00	44.88	-0.24							
	5.791	LC1	-20.35	0.06	-0.09	0.00	44.88	-0.24	109) Check of the maximum allowable bending moment about						
3	Continuous m	embere 3 (N	Member No. 41	43)											
-	0.000	LC1	-42.78	0.01	15.29	0.02	-29.06	-0.02	101) Check of shear flow in top flange						
	3.011	LC1	-42.77	0.01	15.32	0.02	-29.06	-0.02							
_	0.000	LC1	-42.78	0.01	15.29	0.02	-29.06		103) Check of shear flow in bottom flange						
	6.274	LC4	-0.58	-0.13	0.10	0.02	0.74		104) Check of the allowable bending moment in top flange						
	6.274	1C4	-0.58	-0.13	0.10	0.00	0.74		105) Check of the allowable bending moment in bottom flange						
	0.000	LC1	-42.78	0.01	15.29	0.02	-29.06		106) Check of the minimum allowable axial force acting on cro						
	0.000	LC1	-42.78	0.01	15.29	0.02	-29.06		107) Check of the maximum allowable axial force acting on ch						
	0.000	LC1	-43.30	0.01	21.44	0.02	-84.24	0.01							
	0.000	LC1	-43.30	0.01	21.44	0.02	-84.24	0.01	,						
4	Continuous m	embers 4 (M	Member No. 33	.34)											

Figure 4.8: Window 3.2 Governing Internal Forces by Set of Members

This window shows the internal forces that result in the maximum design ratios in the design of each set of members.

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### 4.8 Parts List by Member

Finally, RF-STEEL Plastic provides a summary of all cross-sections used in the design case.

А	B	С	D	F (	F Í	G	H Í	
Cross-Section	Number of			Surface Area	Volume			Total Weight
Description	Members			[m <sup>2</sup> ]	[m 3]			[t]
1 - HEA 360	6			65.88	0.51			4.0
2 - IPE 360 3 - IPE 450	8	3.01	24.09	35.65	0.21	67.33	202.76	1.6
2 - IPE 360	8	3.26	26.10	35.23	0.19	57.09	186.26	1.4
2 - IPE 360	8	6.27	50.19	67.76	0.37	57.09	358.20	2.8
1 - HEA 360	4	3.00	12.00	21.96	0.17	112.10	336.29	1.3
10 - HEA 140	3	3.00	9.00	7.11	0.03	24.66	73.99	0.2
10 - HEA 140	2	3.55	7.09	5.60	0.02	24.66	87.46	0.1
10 - HEA 140	1	4.09	4.09	3.23	0.01	24.66	100.98	0.1
15 - HEA 200	4	3.00	12.00	13.68	0.06	42.26	126.77	0.5
6 - HEA 160	3	3.00	9.00	8.19	0.03	30.43	91.30	0.2
6 - HEA 160	2	3.55	7.09	6.45	0.03	30.43	107.92	0.2
6 - HEA 160	1	4.09	4.09	3.73	0.02	30.43	124.60	0.1
7 - HEA 120	4	6.27	25.10	17.06	0.06	19.89	124.80	0.4
9 - IPE 200	8	6.25	50.00	38.50	0.14	22.36	139.73	1.1
6 - HEA 160	2	6.55	13.09	11.91	0.05	30.43	199.22	
6 - HEA 160	1	7.09	7.09	6.46	0.03	30.43	215.90	0.2
12 - QRO 80x4   DIN 59410:1974	25	5.00	125.00	39.13	0.15	9.42	47.10	1.10
13 - Circle 24	4	7.81	31.24	2.36	0.01	3.55	27.74	0.1
13 - Circle 24	8	8.02	64.18	4.84	0.03	3.55	28.49	0.2
	102		516.46	394.74	2.13			16.7
	Description           1 - HEA 360           2 - IPE 360           2 - IPE 360           2 - IPE 360           1 - HEA 360           10 - HEA 140           10 - HEA 140           15 - HEA 200           6 - HEA 160           7 - HEA 120           9 - IPE 200           6 - HEA 160           6 - HEA 160           12 - QRO 80x4   DIN 59410:1974           13 - Cricle 24	Cross-Section Description         Number of Members           1 - HEA 360         6           2 - IPE 360         3 - IPE 450           2 - IPE 360         8           2 - IPE 360         8           1 - HEA 360         4           10 - HEA 140         3           10 - HEA 140         2           10 - HEA 140         3           6 - HEA 160         1           6 - HEA 160         4           6 - HEA 160         1           7 - HEA 120         4           9 - IPE 200         8           6 - HEA 160         1           13 - Grade 24         4	Cross-Section Description         Number of Members         Length [m]           1 - HEA 360         6         6.00           2 - IPE 360         3 - IPE 450         8         3.01           2 - IPE 360         8         3.26         3.17           2 - IPE 360         8         3.26         3.26           2 - IPE 360         8         6.27         1           1 - HEA 360         4         3.00         10         -14EA 140         3         3.00           10 - HEA 140         2         3.55         11         14.09         1         4.09           15 - HEA 160         3         3.00         1         4.09         -16         4.09           6 - HEA 160         1         4.09         -16         4.627         -16         -2.55         -5.16           6 - HEA 160         1         4.09         -1         -4.09         -2.55         -5.10           7 - HEA 120         4         6.27         -5.55         -6.1EA 160         1         7.09           9 - IPE 200         8         6.255         -5.00         13 - Crocle 24         4         7.81	Cross-Section Description         Number of Members         Length [m]         Total Length [m]           1 - HEA 360         6         600         36.00           2 - IPE 360         8         3.01         24.09           2 - IPE 360         8         3.26         26.10           2 - IPE 360         8         3.26         26.10           1 - HEA 360         4         3.00         12.00           10 - HEA 140         3         3.00         9.00           10 - HEA 140         1         4.09         4.09           15 - HEA 160         3         3.00         12.00           6 - HEA 160         3         3.00         9.00           16 - HEA 160         1         4.09         4.09           6 - HEA 160         3         3.00         9.00           6 - HEA 160         2         3.55         7.09           6 - HEA 160         1         4.09         4.09           9 - IPE 200         8         6.25         50.00           6 - HEA 160         2         6.55         13.09           6 - HEA 160         2         6.55         13.09           6 - HEA 160         2         6.55         13.09<	Cross-Section Description         Number of Members         Length [m]         Total Length [m]         Surface Area [m]           1 - HEA 360         6         6         0.0         36.00         65.88           2 - IPE 360         3 - IPE 450         8         3.01         24.09         35.65           2 - IPE 360         8         3.26         2.610         35.65           2 - IPE 360         8         3.26         2.610         35.65           1 - HEA 360         4         3.00         12.00         21.96           10 - HEA 140         3         3.00         9.00         7.11           10 - HEA 140         1         4.09         4.09         3.23           15 - HEA 160         3         3.00         9.00         8.19           6 - HEA 160         1         4.09         4.09         3.23           15 - HEA 160         1         4.09         4.09         3.73           7 - HEA 120         4         6.27         25.10         17.06           6 - HEA 160         2         6.55         13.09         11.99           6 - HEA 160         2         6.55         13.09         3.9.00           9 - IP 200         8 <td>Cross-Section Description         Number of Members         Length [m]         Total Length [m]         Surface Area [m<sup>3</sup>]         Volume [m<sup>3</sup>]           1 - HEA 360         6         6         0.0         36.00         6         8.0.51           2 - IPE 360         8         3.01         24.09         35.65         0.21           2 - IPE 360         8         3.26         26.10         35.23         0.19           1 - HEA 360         8         6.27         50.19         67.76         0.37           1 - HEA 360         4         3.00         9.00         7.11         0.03           1 - HEA 140         3         3.00         9.00         7.11         0.03           10 - HEA 140         2         3.55         7.09         5.60         0.02           10 - HEA 140         3         3.00         9.00         7.11         0.03           6 - HEA 160         1         4.09         4.09         3.23         0.01           5 - HEA 160         2         3.55         7.09         6.45         0.03           6 - HEA 160         1         4.09         3.03         9.00         3.73         0.02           9 - IPE 200         8</td> <td>Cross-Section Description         Number of Members         Length [m]         Total Length [m]         Surface Area [m]         Volume [m]         Unit Weight [m]           1 - HEA.360         6         6         00         36.00         65.88         0.51         112.10           2 - IPE 360         8         3.01         24.09         35.65         0.21         67.33           2 - IPE 360         8         3.26         26.10         35.23         0.19         57.09           1 - HEA.360         4         3.00         12.00         21.96         0.17         112.10           1 - HEA.360         4         3.00         9.00         7.71         0.03         24.66           10 - HEA.140         2         3.55         7.09         5.60         0.02         24.66           15 - HEA.200         4         3.00         9.00         7.11         0.03         24.66           15 - HEA.100         3         3.00         9.00         8.19         0.03         30.43           6 - HEA.160         1         4.09         4.09         3.73         0.02         30.43           6 - HEA.160         1         4.09         4.09         3.850         0.14</td> <td>Cross-Section Description         Numbers Members [m]         Length [m]         Total Length [m]         Surface Area [m^2]         Volume [m^3]         Unit Weight [kg/m]         Weight [kg/m]           1 - HEA 360         6         600         36.00         65.88         0.51         112.10         672.59           2 - IPE 360         8         3.01         24.09         35.65         0.21         67.33         202.76           2 - IPE 360         8         3.26         26.10         35.53         0.19         57.09         186.26           2 - IPE 360         8         6.27         50.19         67.76         0.37         57.09         356.20           1 - HEA 380         4         3.00         9.00         7.11         0.03         24.66         73.99           10 - HEA 140         2         3.55         7.09         15.60         0.02         24.66         100.98           15 - HEA 160         1         4.09         4.09         3.23         0.01         24.66         100.98           6 - HEA 160         1         4.09         4.09         3.73         0.02         20.466         170.99           6 - HEA 160         1         4.09         4.09         3.73</td>	Cross-Section Description         Number of Members         Length [m]         Total Length [m]         Surface Area [m <sup>3</sup> ]         Volume [m <sup>3</sup> ]           1 - HEA 360         6         6         0.0         36.00         6         8.0.51           2 - IPE 360         8         3.01         24.09         35.65         0.21           2 - IPE 360         8         3.26         26.10         35.23         0.19           1 - HEA 360         8         6.27         50.19         67.76         0.37           1 - HEA 360         4         3.00         9.00         7.11         0.03           1 - HEA 140         3         3.00         9.00         7.11         0.03           10 - HEA 140         2         3.55         7.09         5.60         0.02           10 - HEA 140         3         3.00         9.00         7.11         0.03           6 - HEA 160         1         4.09         4.09         3.23         0.01           5 - HEA 160         2         3.55         7.09         6.45         0.03           6 - HEA 160         1         4.09         3.03         9.00         3.73         0.02           9 - IPE 200         8	Cross-Section Description         Number of Members         Length [m]         Total Length [m]         Surface Area [m]         Volume [m]         Unit Weight [m]           1 - HEA.360         6         6         00         36.00         65.88         0.51         112.10           2 - IPE 360         8         3.01         24.09         35.65         0.21         67.33           2 - IPE 360         8         3.26         26.10         35.23         0.19         57.09           1 - HEA.360         4         3.00         12.00         21.96         0.17         112.10           1 - HEA.360         4         3.00         9.00         7.71         0.03         24.66           10 - HEA.140         2         3.55         7.09         5.60         0.02         24.66           15 - HEA.200         4         3.00         9.00         7.11         0.03         24.66           15 - HEA.100         3         3.00         9.00         8.19         0.03         30.43           6 - HEA.160         1         4.09         4.09         3.73         0.02         30.43           6 - HEA.160         1         4.09         4.09         3.850         0.14	Cross-Section Description         Numbers Members [m]         Length [m]         Total Length [m]         Surface Area [m^2]         Volume [m^3]         Unit Weight [kg/m]         Weight [kg/m]           1 - HEA 360         6         600         36.00         65.88         0.51         112.10         672.59           2 - IPE 360         8         3.01         24.09         35.65         0.21         67.33         202.76           2 - IPE 360         8         3.26         26.10         35.53         0.19         57.09         186.26           2 - IPE 360         8         6.27         50.19         67.76         0.37         57.09         356.20           1 - HEA 380         4         3.00         9.00         7.11         0.03         24.66         73.99           10 - HEA 140         2         3.55         7.09         15.60         0.02         24.66         100.98           15 - HEA 160         1         4.09         4.09         3.23         0.01         24.66         100.98           6 - HEA 160         1         4.09         4.09         3.73         0.02         20.466         170.99           6 - HEA 160         1         4.09         4.09         3.73

Figure 4.9: Window 4.1 Parts List by Member

By default, this list contains only the designed members. If you need a parts list for all members of the model, select the corresponding option in the *Other* tab of the *Details* dialog box (see Figure 3.2, page 17).

#### Part No.

The program automatically assigns part numbers to similar members.

#### **Cross-Section Description**

This column shows the cross-section numbers and descriptions.

#### **Number of Members**

This column shows for each part how many similar members are used.

#### Length

This column displays the length of a single member.

#### **Total Length**

This column shows the product determined from the previous two columns.

#### Surface Area



Details.

For each part, the program indicates the surface area relative to the total length. The surface area is determined from the *Surface* of the cross-sections that can be seen in Windows 1.3 and 2.1 through 2.5 in the cross-section properties (see Figure 2.8, page 14).



#### Volume

The volume of a part is determined from the cross-sectional area and the total length.

#### **Unit Weight**

The *Unit Weight* is the weight of the section relative to the length of one meter. For tapered cross-sections, the program averages both cross-section properties.

#### Weight

The values of this column are determined from the respective product of the entries in column C and G.

#### **Total Weight**

The final column indicates the total weight of each part.

#### Sum

At the bottom of the list, you find a summary of the values in the columns B, D, E, F, and I. The last row of the *Total Weight* column informs you about the total amount of the required steel.

### 4.9 Parts List by Set of Members

	А	B	С	D	E	F	G	H (	1
art	Set of Members	Number	Length	Total Length	Surface Area	Volume	Unit Weight	Weight	Total Weight
o.	Description	of Sets	[m]	[m]	[m <sup>2</sup> ]	[m <sup>3</sup> ]	[kg/m]	[kg]	[t]
1	Continuous members 1	1	12.55	12.55	17.33	0.10	59.55	747.23	0.74
	Continuous members 2	1	12.55	12.55	17.33	0.10	59.55	747.23	0.74
3	Continuous members 3	1	12.55	12.55	8.53	0.03	19.89	249.60	0.25
4	Continuous members 4	1	12.55	12.55	8.53	0.03	19.89	249.60	0.25
Jm		4		50.19	51.73	0.25			1.99

Figure 4.10: Window 4.2 Parts List by Set of Members

The final results window is displayed if you have selected at least one set of members for design. It summarizes entire structural groups (for example, a horizontal beam) in a parts list.

The columns are described in the previous chapter. If different cross-sections are used in the set of members, the program averages the surface area, volume, and cross-section weight.



# 5. Evaluation of Results

You can evaluate the design results in different ways. The buttons below the upper table can help you evaluate the results.

	A	B	С	D	E					F	-							
	Member	Location	Load	Design														
No.	No.	x [m]	Case	Ratio	1				Des	ign Accord	ling to Formu	la						
1	HEA 360																	
	1	6.000	LC4				heck of shear fl		ge									
	32	0.000	LC2				heck of shear fl											
	1	6.000	LC4				heck of shear fl											
	1	3.000	LC4				heck of the allo											
	1	3.000	LC4				heck of the allo											
	31	0.000	LC1				heck of the min											
	31	0.000	LC1				heck of the ma											
	21	6.000	LC2				heck of the min											
	21	6.000	LC2	0.41	≤1	109) C	heck of the ma	kimum allowab	le bending	moment ab	out the major	or axis						
			Max:	0.87	≤ 1	۲					🗈 🖺	> 1.	0	•	7	2	1	3
- Yiel		of top flange					f <sub>y,fo</sub>		kN/cm <sup>2</sup>					+	30	0.0		
Yiel	d strength d strength	of top flange					fy. t. fo	12.60	kN/cm <sup>2</sup>				t		30	0.0		
Yiel Yiel Tor	d strength d strength sional mod	of top flange ulus of top fla	inge				fy.t.fo IT.fo	12.60 51.62	kN/cm <sup>2</sup> cm <sup>4</sup>				t	17.5	30	W	7.0	
Yiel Yiel Tor Prin	d strength d strength sional mode nary torsion	of top flange ulus of top fla al moment w	inge ith respect	to web center			f <sub>y,τ,fo</sub> IT,fo Tprim	12.60 51.62 0.018	kN/cm <sup>2</sup> cm <sup>4</sup> kNm				ţ	1 <sup>2</sup>	30	W	7.0	
Yiel Yiel Tor Prin Sec	d strength d strength sional mode nary torsion condary tors	of top flange ulus of top fla al moment w sional momer	inge ith respect it with resp	ect to web cente	r		f <sub>y,τ,fo</sub> I <sub>T,fo</sub> T <sub>prim</sub> T <sub>sec</sub>	12.60 51.62 0.018 0.000	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm				0.0	- <sup>12</sup>	30	W	7.0	
Yiel Yiel Ton Prin Sec She	d strength d strength sional mode nary torsion condary tors ear force in	of top flange ulus of top fla al moment w sional momen top flange in	inge ith respect it with resp local y-dire	ect to web cente	r		fy.τ.fo           IT.fo           Tprim           Tsec           Vy.fo	12.60 51.62 0.018 0.000 1.877	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN				350.0	17.8	30	W	7.0	
Yiel Yiel Tor Prin Sec She Plas	d strength d strength sional mode nary torsion condary tors ear force in stic shear c	of top flange ulus of top fla al moment w sional momen top flange in capacity of to	inge ith respect it with resp local y-dire p flange in	ect to web cente ction local y-direction	r		fy.τ,fo           IT,fo           Tprim           Tsec           Vy,fo           Vpl,y,fo	12.60 51.62 0.018 0.000 1.877 661.329	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kN				350.0	17.8	30	W	7.0	
Yiel Yiel Tor Prin Sec She Plas	d strength d strength sional mode any torsion condary tors ar force in stic shear o nary torsion	of top flange ulus of top fla al moment w sional momen top flange in capacity of to al moment in	inge ith respect it with resp local y-dire p flange in top flange	ect to web cente ction local y-direction	r		fy, τ, fo           IT, fo           Tprim           Tsec           Vy, fo           Vpl,y, fo           Tprim, fo	12.60 51.62 0.018 0.000 1.877 661.329 0.006	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kN kN				350.0	ि मि 2 मि	30	2	7.0	
Yiel Yiel Ton Prin Sec She Plas Prin Plas	d strength d strength sional mode any torsion condary torsion stic shear c nary torsion stic torsion	of top flange ulus of top fla al moment w sional momer top flange in capacity of to al moment in al capacity of	inge ith respect it with resp local y-dire p flange in top flange	ect to web cente ction local y-direction	r		fy, τ, fo           IT, fo           Tprim           Tsec           Vy, fo           Vpl,y, fo           Tprim, fo           Tpl, fo	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kN kN				350.0		30	2	7.0	•
Yiel Yiel Tor Prin Sec She Plas Prin Plas She	d strength d strength sional mode any torsion ear force in stic shear o hary torsion stic torsion as stress in	of top flange ulus of top fla al moment w sional momer top flange in sapacity of to al moment in al capacity of top flange	inge ith respect it with resp local y-dire p flange in top flange top flange	ect to web cente ction local y-direction		qe	Fy.τ.fo           IT.fo           Tprim           Tsec           Vy.fo           Vpl.y.fo           Tprim, fo           Tpl.fo           τfo	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kN kNm kNm	≤ 1.000			350.0		30	2	7.0	•
Yiel Yiel Tor Prin Sec She Plas Prin Plas She	d strength d strength sional mode any torsion ear force in stic shear o hary torsion stic torsion as stress in	of top flange ulus of top fla al moment w sional momer top flange in sapacity of to al moment in al capacity of top flange	inge ith respect it with resp local y-dire p flange in top flange top flange	ect to web cente ction local y-direction		ge	fy, τ, fo           IT, fo           Tprim           Tsec           Vy, fo           Vpl,y, fo           Tprim, fo           Tpl, fo	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618 0.04	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kN kNm kNm	≤ 1.000			350.0		30	2	7.0	
Yiel Yiel Tor Prin Sec She Plas Prin Plas She	d strength d strength sional mode any torsion ear force in stic shear o hary torsion stic torsion as stress in	of top flange ulus of top fla al moment w sional momer top flange in sapacity of to al moment in al capacity of top flange	inge ith respect it with resp local y-dire p flange in top flange top flange	ect to web cente ction local y-direction		ge	Fy.τ.fo           IT.fo           Tprim           Tsec           Vy.fo           Vpl.y.fo           Tprim, fo           Tpl.fo           τfo	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618 0.04	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kN kNm kNm	≤ 1.000			350.0		30	2	7.0	
Yiel Yiel Tor Prin Sec She Plas Prin Plas She	d strength d strength sional mode any torsion ear force in stic shear o hary torsion stic torsion as stress in	of top flange ulus of top fla al moment w sional momer top flange in sapacity of to al moment in al capacity of top flange	inge ith respect it with resp local y-dire p flange in top flange top flange	ect to web cente ction local y-direction		ge	Fy.τ.fo           IT.fo           Tprim           Tsec           Vy.fo           Vpl.y.fo           Tprim, fo           Tpl.fo           τfo	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618 0.04	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kN kNm kNm	≤ 1.000			350.0	-	30	2	7.0	
Yiel Yiel Tor Prin Sec She Plas Prin Plas She	d strength d strength sional mode any torsion ear force in stic shear o hary torsion stic torsion as stress in	of top flange ulus of top fla al moment w sional momer top flange in sapacity of to al moment in al capacity of top flange	inge ith respect it with resp local y-dire p flange in top flange top flange	ect to web cente ction local y-direction		ge	Fy.τ.fo           IT.fo           Tprim           Tsec           Vy.fo           Vpl.y.fo           Tprim, fo           Tpl.fo           τfo	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618 0.04	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kN kNm kNm	≤ 1.000			350.0		30	2	7.0	
Yiel Yiel Tor Prin Sec She Plas Plas Prin Plas	d strength d strength sional mode any torsion ear force in stic shear o hary torsion stic torsion as stress in	of top flange ulus of top fla al moment w sional momer top flange in sapacity of to al moment in al capacity of top flange	inge ith respect it with resp local y-dire p flange in top flange top flange	ect to web cente ction local y-direction		ge	Fy.τ.fo           IT.fo           Tprim           Tsec           Vy.fo           Vpl.y.fo           Tprim, fo           Tpl.fo           τfo	12.60 51.62 0.018 0.000 1.877 661.329 0.006 5.618 0.04	kN/cm <sup>2</sup> cm <sup>4</sup> kNm kNm kN kN kNm kNm	≤ 1.000			350.0		30	2	7.0	<b>•</b>

Figure 5.1: Button for evaluation of results

The buttons have the following functions:

Button	Description	Function
	Result combination	Creates a new result combination from the governing load cases and load combinations
	Color bar	Shows or hides the colored reference scales in the re- sults windows
> 1,0	Filter parameters	Represents the criterion for filtering the tables: Design ratios greater than 1, maximum value, or user- defined limit
<b>7</b> ,1	Apply filter	Shows only rows where the filter parameters are valid (ratio > 1, maximum, user-defined value)
2	Result diagrams	Opens the dialog box <i>Result Diagram on Member</i> → Chapter 5.2, page 33
	Excel export	Exports the table to MS Excel / OpenOffice → Chapter 7.4.2, page 44
<b>A</b>	Member selection	Allows for the graphical selection of a member to display its results in the table
۲	View mode	Goes to the RFEM work window for changing the view

Table 5.1: Buttons in the results windows 2.1 through 2.5



### 5.1 Results on the RFEM model

You can also evaluate the design results in the RFEM work window.

#### RFEM background graphic and view mode

The RFEM work window in the background is useful for finding the position of a member in the model. The member selected in the RF-STEEL Plastic results window is highlighted in the selection color in the background graphic. Furthermore, an arrow indicates the member's x-location displayed in the currently selected table row.

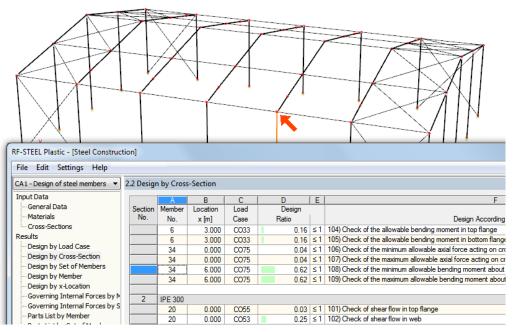


Figure 5.2: Indication of the member and the current *Location x* in the RFEM model

If you cannot improve the display by moving the RF-STEEL Plastic window, click [Jump to Graphic] to activate the *View Mode*. Thus, you hide the module window so that you can change the display in the RFEM graphical user interface. In the view mode, you can use the functions of the *View* menu, for example zooming, moving, or rotating the display. The indication arrow remains visible.

To return to the RF-STEEL Plastic module, click [Back].

#### **RFEM work window**

You can also graphically check the design ratios in the RFEM model. First, click [Graphics] to exit the design module. In the RFEM work window, the design ratios are now displayed like the internal forces of a load case.

To display or hide design results, use the [Show Results] button known from the display of internal forces. To display the result values, click the [Show Values] button in the toolbar to the right.

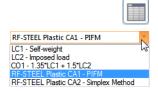
The RFEM tables are of no relevance for the evaluation of design results.

To set the design cases, you can use the list in the toolbar.



Graphics







To adjust the results display, use the *Display* navigator below the entry  $Results \rightarrow Members$ . The display of the design ratios is *Two-Colored* by default.

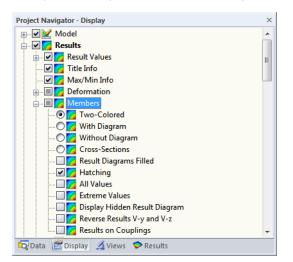


Figure 5.3: *Display* navigator: Results  $\rightarrow$  Members

When you select a multicolor representation (options *With/Without Diagram* or *Cross-Sections*), the color scale panel becomes available. It provides the common control functions described in the RFEM manual, Chapter 3.4.6.

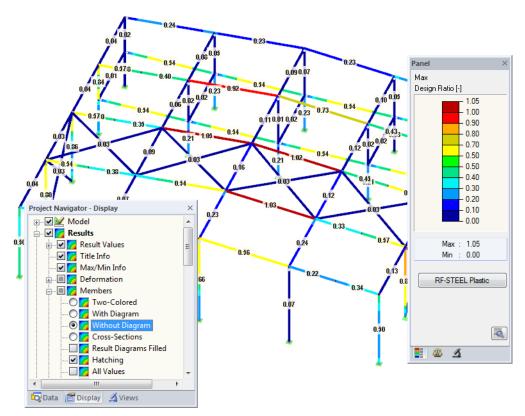


Figure 5.4: Design ratios with display option Without Diagram

You can transfer the graphics of the results to the printout report (see Chapter 6.2, page 36). To return to the add-on module, click [RF-STEEL Plastic] in the panel.

RF-STEEL Plastic

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### 5.2 Result Diagrams

You can also graphically evaluate a member's result distributions in a result diagram.

To do this, select the member (or set of members) in the RF-STEEL Plastic results window by clicking in the corresponding table row of the member. Then, open the *Result Diagram on Member* dialog box by clicking the button shown on the left. The button is located below the upper results table (see Figure 5.1, page 30).

To display the result diagrams, select the command from the RFEM menu

#### Results $\rightarrow$ Result Diagrams for Selected Members

or use the button in the RFEM toolbar shown on the left.

A window opens, graphically presenting the distribution of the maximum design values on the member or set of members.

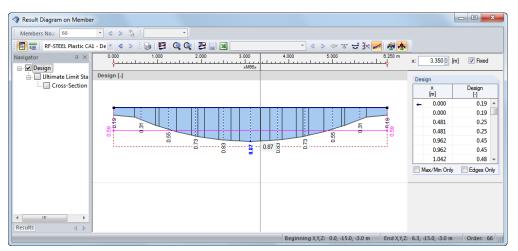
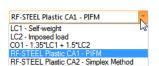


Figure 5.5: Dialog box Result Diagram on Member

To select the relevant RF-STEEL Plastic design case, use the list in the toolbar of the dialog box.

The Result Diagram on Member dialog box is described in the RFEM manual, Chapter 9.5.



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### 5.3 Filter for Results

The results windows in RF-STEEL Plastic allow you to sort the results by various criteria. In addition, you can use the filter options to graphically evaluate the results as described in Chapter 9.7 of the RFEM manual.

In RF-STEEL Plastic, you can also use the *Visibilities* (see RFEM manual, Chapter 9.7.1) to filter the members for evaluation.

#### **Filtering designs**

The design ratios can easily be used as filter criteria in the RFEM work window which you can access by clicking [Graphics]. To apply this filter function, the panel must be displayed. If it is not, select in the RFEM menu

#### View $\rightarrow$ Control Panel (Color Scale, Factors, Filter)

or use the toolbar button shown on the left.

The panel is described in the RFEM manual, Chapter 3.4.6. You define the filter settings for the results in the first panel tab (Color spectrum). Because this register is not available for the two-colored results display, you have to use the *Display* navigator and set the display options *With/Without Diagram* or *Cross-Sections* first.

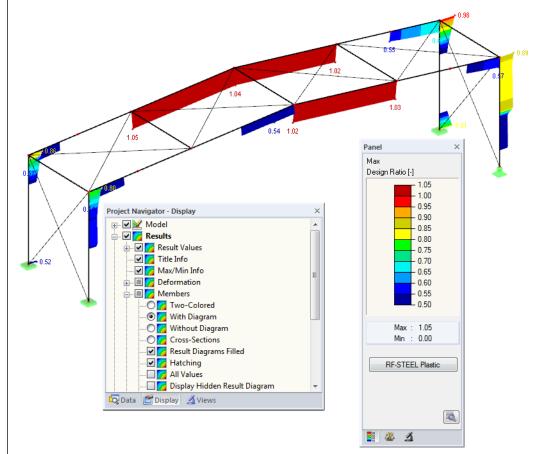


Figure 5.6: Filtering design ratios with adjusted color spectrum

As the figure above shows, the color spectrum can be set in such a way that only ratios higher than 0.50 are shown in a color range between blue and red.

If you select the *Display Hidden Result Diagram* option in the *Display* navigator (*Results* $\rightarrow$  *Members*), you can display all design ratio diagrams that are not covered by the color spectrum. Those diagrams will be represented by dotted lines.





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#### Filtering members

In the *Filter* tab of the control panel, you can specify the numbers of particular members to display their results exclusively, that is, filtered. This function is described in the RFEM manual, Chapter 9.9.3.

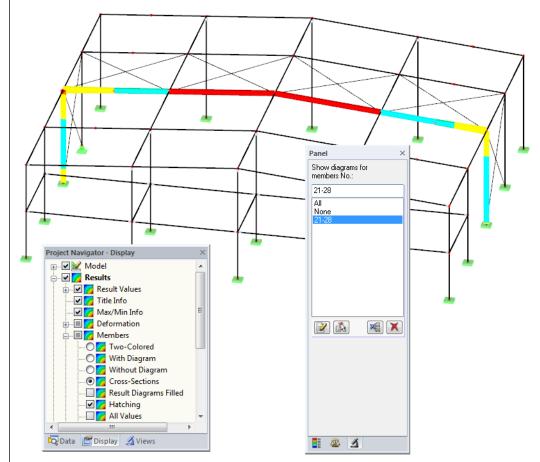


Figure 5.7: Member filter for the design ratios of a frame

Unlike the partial view function (*Visibilities*), the graphic displays the entire model. The figure above shows the design ratios of a frame. The remaining members are displayed in the model but are shown without design ratios.





#### **Printout** 6.

#### 6.1 **Printout Report**

Like in RFEM, the program generates a printout report for the RF-STEEL Plastic results, to which you can add graphics and descriptions. The selection in the printout report determines which data from the design module will be included in the final printout.



The printout report is described in the RFEM manual. In particular, Chapter 10.1.3.4 Selecting Data of Add-on Modules describes how to select input and output data from add-on modules for the printout report.

For large structural systems with many design cases, it is recommended to split the data into several printout reports, thus allowing for a clearly-arranged printout.

#### **Graphic Printout** 6.2

In RFEM, you can add every picture displayed in the work window to the printout report or send it directly to a printer. In this way, you can also prepare the design ratios displayed on the RFEM model for the printout.



Printing graphics is described in the RFEM manual, Chapter 10.2.

#### **Designs on the RFEM Model**

To print the current graphic of the design ratios, select the command in the menu

#### File $\rightarrow$ Print

or use the toolbar button shown on the left.

ĺ	🔊 R	FEM 5	.02.272	2 (64bi	t) - [Stee	l Construct	ion]			
	:4	<u>F</u> ile	<u>E</u> dit	<u>V</u> iew	Insert	<u>C</u> alculate	<u>R</u> esults	Tools	Ta <u>b</u> le	<u>O</u> ptions
	:	2	3 3		1 🙀 🖻		🖉 🍕	Q 🔁	2   🗉	
	1	- 9	<i>%</i> 1	· •7-	Print	Graphic	- <u>9××</u> 🕅	1 🔁	· 🗖 -	🔷 - 🗊

Figure 6.1: Button [Print Graphic] in RFEM toolbar

#### **Result diagrams**

1

In the Result Diagram on Member dialog box, you can also send the graphic with the design values to the report using the [Print] button. Furthermore, you can print the graphic directly.

(	Result Diagram on Membe	r			
	Members No.: 67	- < > 🏷		🙀 🖾 🖓	🎅 🔒 🗷
	RF-STEEL Plastic CA	1 - De 🝸 \land 🔈		Print	
	Navigator 🛛 🕂 🗙	0.000	1.000	2.000 3.0	00
	Design	<del>             </del>		3	M07»
	Ultimate Limit Sta	Design [-]			
	Cross-Section				

Figure 6.2: Button [Print] in the dialog box Result Diagram on Member

The following dialog box appears.



eneral Options Color Scale Factors B	order and Stretch Factors							
Graphic Picture	Window To Print Graphic Size							
Directly to a printer	Current only     As screen view							
To a printout report: PR1	More     More     Window filling							
) To the Clipboard								
D To 3D PDF								
-								
Graphic Picture Size and Rotation	Options							
Use whole page width	Show results for selected x-location in result diagram							
问 Use whole page height	Lock graphic picture (without update)							
eight: 40 → [% of page]								
	Show printout report on [OK]							
Rotation: 0 🚔 [°]								
leader of Graphic Picture								
RF-STEEL Plastic - Design Ratio, CA1, Isometric								

Figure 6.3: Dialog box Graphic Printout, tab General

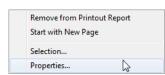
This dialog box is described in the RFEM manual, Chapter 10.2. The manual also describes the *Options* and *Color Scale* tab.

To move a graphic within the printout report, use the drag-and-drop function.

To adjust a graphic in the printout report after the fact, right-click the corresponding entry in the navigator of the printout report. The *Properties* option in the context menu opens the *Graphic Printout* dialog box, offering various options for adjustment.

Graphic Printout				×
General Options Color Scale Fac	tors Border and Stretch	Factors		
Script  Proportional  Constant  Factor:  1	Symbols  Proportional Constant  Factor:		Frame  None  Framed  Title box	
Print Quality  Standard (max 1000 x 1000 Pixels  Maximum (max 5000 x 5000 Pixels  Max number of pixels:		Color Carayscale Texts and All colore	l lines in black	
0			ОК	Cancel

Figure 6.4: Dialog box Graphic Printout, tab Options





# 7. General Functions

This chapter describes useful menu functions and export options for the designs.

# 7.1 Design Cases

Design cases allow you to group members for the design. In this way, you can consider groups of structural components or analyze members with particular design specifications (for example, changed materials, partial safety factors, or optimization).

It is no problem to analyze the same member or set of members in different design cases.

To calculate a RF-STEEL Plastic design case, you can also use the load case list in the RFEM toolbar.

### Creating new design case

To create a new design case, select in the RF-STEEL Plastic menu

File  $\rightarrow$  New Case.

The following dialog box appears:

Vew RF-S	TEEL Plastic Case
No.	Description
2	Design of steel members according to PIFM -

Figure 7.1: Dialog box New RF-STEEL Plastic Case

In this dialog box, enter a *No*. (one that is still available) for the new design case. An appropriate *Description* will make the selection in the load case list easier.

Click [OK] to open the 1.1 *General Data* window of RF-STEEL Plastic where you can enter the design data.

### Renaming design case

To change the description of a design case, select in the RF-STEEL Plastic menu

### File ightarrow Rename Case.

The following dialog box appears:

Rename I	RF-STEEL Plastic Case	X
No. 2	Description New Description	•
٢		OK Cancel

Figure 7.2: Dialog box Rename RF-STEEL Plastic Case

In this dialog box, you can specify a different *Description* as well as a different *No*. for the design case.





### Copying design case

To copy the input data of the current design case, select from the RF-STEEL Plastic menu

```
File \rightarrow Copy Case.
```

The following dialog box appears:

Copy RF-	STEEL Plastic Case
Copy fro	om Case
CA1 - E	Design acc. to PIFM (Partial Internal Forces Met 💌
New Ca	se
No.:	Description:
3	Copy of case 1 (Simplex Method)
()	
	OK Cancel

Figure 7.3: Dialog box Copy RF-STEEL Plastic

Define the No. and, if necessary, a Description for the new case.

### **Deleting design case**

To delete design cases, select from the RF-STEEL Plastic menu

```
\textbf{File} \rightarrow \textbf{Delete Case}.
```

The following dialog box appears:

	le Cases
No.	Description
1	Design of steel members according to Partia
	New Description
3	Copy of case 1 (Simplex Method)
D	OK Cancel

Figure 7.4: Dialog box Delete Case

First, select the design case from the Available Cases. To delete the selected case, click [OK].





# 7.2 Cross-Section Optimization

The design module offers you the option to optimize overstressed or little utilized crosssections. To do this, select from the lists in column D or E of the 1.3 *Cross-Sections* window whether to determine the cross-section *From current row* or from the user-defined *Favorites* (see Figure 2.6, page 12). Alternatively, you can start the cross-section optimization in the results windows by using the context menu.

	A	В	С	D	E	F						
Section	Member	Location	Load	Design								
No.	No.	x [m]	Case	Ratio		Design According to Formula						
1 HE A 280   Euronorm 53-62												
	5	0.000	RC1	0.03	≤1	1 101) Check of shear flow in top flange						
	5	0.0	Gata	ross-Section		Doubleclick arflow in web						
	5	0.0	-			Doubleclick	ar flow in bottom flange					
	13	4.0	Info Ab	out Cross-Sectio	on		allowable bending moment in top flange					
	13	4.0	Ontimi	ze Cross-Section			allowable bending moment in bottom flange					
	13	0.0	_				ninimum allowable axial force acting on cross-section					
	13	0.0	Cross-S	Section Optimiza	tion	Parameters	naximum allowable axial force acting on cross-section					
	13	4.000	RC1				minimum allowable bending moment about the major axis					
	13	4.000	RC1	0.62	≤1	109) Check of the	maximum allowable bending moment about the major axis					

Figure 7.5: Context menu for cross-section optimization

During the optimization process, the module determines the cross-section that fulfills the design conditions in the most optimal way, that is, comes as close as possible to the maximum allowable design ratio specified in the *Details* dialog box (see Figure 3.2, page 17). The required cross-section properties are determined with the internal forces from RFEM. If another crosssection proves to be more favorable, this new cross-section is used for the design. Then, the graphic in Window 1.3 shows two cross-sections: the original cross-section from RFEM and the optimized one (see Figure 7.7).

For a parametric cross-section, the following dialog box appears when you select 'Yes' from the drop-down list.

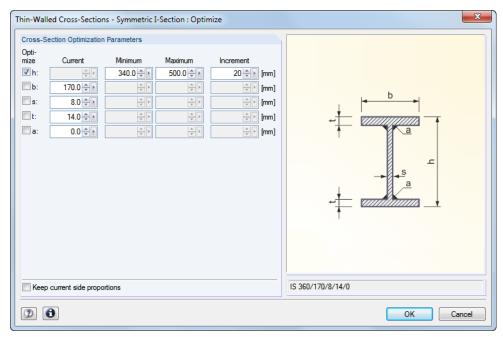


Figure 7.6: Dialog box Welded Cross-Sections - Symmetric I-Section : Optimize

By selecting the check boxes in the *Optimize* column, you decide which parameter(s) you want to modify. This enables the *Minimum* and *Maximum* columns, where you can specify the upper and lower limits of the parameter. The *Increment* column specifies the interval by which the size of the parameter varies during the optimization process.

### **7** General Functions



If you want to *Keep current side proportions*, select the corresponding check box. In addition, you must select at least two parameters for optimization.

Cross-sections built up from rolled cross-sections cannot be optimized.

5

Please note that the internal forces will <u>not</u> be recalculated automatically with the changed cross-sections in the optimization. It is up to you to decide which cross-sections you want to transfer to RFEM for recalculation. Due to the changed stiffnesses in the structural system, the internal forces from the optimized cross-section may vary significantly. Therefore, it is recommended to recalculate the internal forces of the modified cross-section data after the first optimization, and then to optimize the cross-sections once again.

You can export the modified cross-sections to RFEM. To do this, go to the 1.3 *Cross-Sections* window, and then select the command from the menu

#### $\textbf{Edit} \rightarrow \textbf{Export All Cross-Sections to RFEM}.$

Alternatively, you can use the context menu in Window 1.3 to export optimized cross-sections to RFEM.

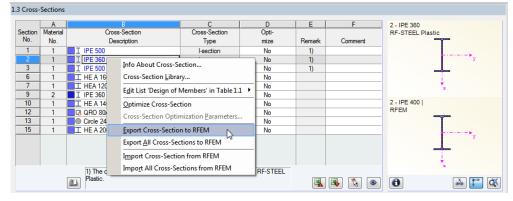


Figure 7.7: Context menu in Window 1.3 Cross-Sections

Before the modified materials are transferred to RFEM, a query appears as to whether you want to delete the results in RFEM and RF-STEEL Plastic.

RF-STEEL Plastic Information No. 53119								
Do you want to transfer the changed cross-sections to RFEM?								
If so, the results of RFEM and RF-STEEL Plastic will be deleted.								
Yes No	]							

Figure 7.8: Query before export of modified cross-sections to RFEM

By confirming the query, and then starting the [Calculation] in the RF-STEEL Plastic module, the RFEM internal forces as well as the checks will be determined in a single calculation run.

If the modified cross-sections are not exported to RFEM, you can reimport the original crosssections in the design module by using the options shown in Figure 7.7. Please note that this option is available in the 1.3 *Cross-Sections* window only.



If you optimize a tapered member, the program modifies the start and end sections of the member. Then, the program linearly interpolates the second moments of area at the intermediate locations. Because these moments are considered with the fourth power, the analyses may be inaccurate if the depths of the start and the end cross-section differ significantly. In such a case, it is recommended to divide the taper into several members, thus modeling the taper layout manually.

### Calculation



# 7.3 Units and Decimal Places

Units and decimal places for RFEM and the add-on modules are managed in one common dialog box. To specify the units for RF-STEEL Plastic, select in the module menu

### Settings $\rightarrow$ Units and Decimal Places.

The dialog box known from RFEM appears. In the *Program / Module* dialog box section, RF-STEEL Plastic is preset.

Units and Decimal Places					×
Program / Module RFEM RF-STEEL Surfaces BF-STEEL Members	RF-STEEL Plastic Output Data	Unit Dec. places	Parts List	Unit	Dec. places
- RF-STEEL EC3 - RF-STEEL AISC - RF-STEEL SIA - RF-STEEL SIA - RF-STEEL GB - RF-STEEL CS - RF-STEEL CS - RF-STEEL NS - RF-STEEL NC-DF - RF-STEEL SP	Stresses: Design ratios: Dimensionless:	kN/cm <sup>2</sup> ▼ 1 ↓ - ▼ 2 ↓ - ▼ 3 ↓	Lengths: Total lengths: Surface areas: Volumes: Weight per length: Weight: Total weight:	m v m v m^2 v kg/m v kg v	
RF-STEEL Plastic     RF-STEEL SANS     RF-STEEL Fatigue Mer     RF-ALUMINIUM     RF-KAPPA     RF-ELTB     RF-ELTB     RF-ELTB     RF-ELPL     RF-CTO-T     PLATE-BUCKLING     RF-CONCRETE Surfac     RF-CONCRETE Surfac     RF-CONCRETE Surfac     RF-CONCRETE Column     RF-PUNCH     RF-TIMBER Pro					
RF-TIMBER AWC	]			ОК	Cancel

Figure 7.9: Dialog box Units and Decimal Places



To reuse the settings in other models, save them as a user-profile. These functions are described in the RFEM manual, Chapter 11.1.3.



# 7.4 Data Exchange

### 7.4.1 Exporting Materials to RFEM

If you adjusted the materials in RF-STEEL Plastic for design, you can export the modified materials to RFEM in a similar way as you export cross-sections. To do this, go to the 1.2 *Materials* window, and then select the command in the menu

#### Edit $\rightarrow$ Export All Materials to RFEM.

Alternatively, you can export the modified materials to RFEM by using the context menu in Window 1.2.

Material Library
Export Material to RFEM
Export <u>A</u> ll Materials to RFEM
Import Material from RFEM
Import All Materials from RFEM

Figure 7.10: Context menu of Window 1.2 Materials

#### Calculation

Before the modified materials are transferred to RFEM, a query appears as to whether you want to delete the results in RFEM. After you confirm the query and start the [Calculation] in RF-STEEL Plastic, the RFEM internal forces and designs are determined in a single calculation run.

If the modified materials are not exported to RFEM, you can transfer the original materials to the design module, using the options shown in Figure 7.10. Please note, however, that this option is only available in the 1.2 *Materials* window.

## 7.4.2 Exporting Results

You can use the RF-STEEL Plastic results also in other programs.

### Clipboard

To copy cells selected in the results windows to the Clipboard, press the keys [Ctrl]+[C]. To insert the cells, for example in a word processor, press [Ctrl]+[V]. The headers of the table columns are not transferred.

### **Printout report**

You can print the data of the RF-STEEL Plastic module into the printout report (see Chapter 6.1, page 36) for export. Then, in the printout report, you can export them by selecting in the report menu

File  $\rightarrow$  Export in RTF.

This function is described in the RFEM manual, Chapter 10.1.11.

### **Excel / OpenOffice**

RF-STEEL Plastic provides a function for the direct data export to MS Excel, OpenOffice.org Calc, or the file format CSV. To open the corresponding dialog box, select on the module menu

#### $\textbf{File} \rightarrow \textbf{Export Tables}.$

The following dialog box appears.

### **7** General Functions



Figure 7.11: Dialog box Export - MS Excel

Having selected the relevant options, you can start the export by clicking [OK]. Excel or OpenOffice are started automatically, that is, you do not need to open the programs before-hand.

<   L	(	≝ -   -						ad-Only] - Microsoft Excel			
File	Ho	me Inse	rt Page La	yout For		ata	Revie	ew View Add-Ins			a 🕜 🗆 🖻
Paste	₫- <i>∛</i>	Calibri B I U 	• 8 • • A A • A • E	<u> </u>	,			Conditional Formatting * Format as Table * Cell Styles * Styles	Here real real real real real real real r	∑ * Sort & Find & C * Sort & Find & Filter * Select * Editing	Translate Document
	B3		. (	f* IPE 500	)						
	А	В	С	D	E	F				G	
1	Section	Member	Location	Load	Desig	ŋ					
2	No.	No.	x [m]	Case	Ratio				De	sign According to Form	ula
3	1	IPE 500									
4		1	6,000	LC4	0,01	≤1	101) (	Check of shear flow in top flan	ge		
5		32	0,000	LC2	0,13	≤1	102) (	Check of shear flow in web			
6		1	6,000	LC4	0,01	≤1	103) Check of shear flow in bottom flange				
7		1	3,000	LC4	0,08	≤1	104) Check of the allowable bending moment in top flange				
8		1	3,000	LC4	0,08	≤1	105) Check of the allowable bending moment in bottom flange				
9		31	0,000	LC1	0,05	≤1	106) Check of the minimum allowable axial force acting on cross-section				
10		31	0,000	LC1	0,05	≤1	107) (	Check of the maximum allowal	ole axial force	acting on cross-section	I
11		21	6,000	LC2	0,39	≤1	108) (	Check of the minimum allowab	le bending mo	ment about the major a	ixis
12		21	6,000	LC2	0,39	≤1	109) (	Check of the maximum allowal	ole bending mo	ment about the major a	axis
13											
14	2	IPE 330									
15		4	0,000	LC4	0,00	≤1	101) (	Check of shear flow in top flan	ge		
16		23	0,000	LC2	0,13	≤1	102) 0	Check of shear flow in web			
17		4	0,000	LC4	0,00	≤1	103) 0	Check of shear flow in bottom	flange		
18		42	3,262	LC4	0,01	≤1	104) 0	Check of the allowable bending	g moment in to	p flange	
19		42	3,262	LC4	0,01	≤1	105) (	Check of the allowable bending	g moment in bo	ttom flange	
20		42	0,000	LC2	0,06	≤1	106) (	Check of the minimum allowab	le axial force a	acting on cross-section	
21		42	0,000	LC2	0,06	≤1	107) (	Check of the maximum allowal	ole axial force	acting on cross-section	1
22		23	0,000	LC2	0,85	≤1	108) (	Check of the minimum allowab	le bending mo	ment about the major a	ixis
23		23	0,000	LC2	0,85	≤1	109) 0	Check of the maximum allowal	ole bending mo	ment about the major a	axis
I ∢ I Ready		2 Design by	y Cross-Secti	on 🧷				[] ◀ [			

Figure 7.12: Results in Excel



# 8. Worked Examples

# 8.1 Doubly Symmetrical I-Section

The following example is presented in [1], page 431. The interaction from axial force and double-bending without warping is analyzed according to PIFM.

### **Cross-Section**

Doubly symmetrical I-section HE B 200

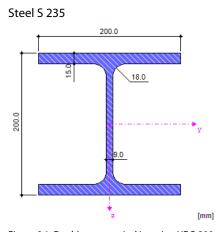


Figure 8.1: Doubly symmetrical I-section HE B 200

#### **Cross-section properties**

Cross-section property	Symbol	Value	Unit
Depth	h	200.00	mm
Width	b	200.00	mm
Web thickness	t <sub>w</sub>	9.00	mm
Flange thickness	t <sub>f</sub>	15.00	mm
Root fillet radius	r	18.00	mm
Depth between flanges	d-2t <sub>f</sub>	170.00	mm
Depth of straight web	d	134.00	mm
Cross-sectional area	A	78.08	cm <sup>2</sup>
Shear area	Ay	50.03	cm <sup>2</sup>
Shear area	Az	15.32	cm <sup>2</sup>
Effective shear area according to EC 3	A <sub>v,y</sub>	62.43	cm <sup>2</sup>
Shear area according to EC 3	A <sub>v,z</sub>	24.83	cm <sup>2</sup>
Plastic shear area	A <sub>pl,y</sub>	60.00	cm <sup>2</sup>
Plastic shear area	A <sub>pl,z</sub>	16.65	cm <sup>2</sup>
Moment of inertia	l <sub>y</sub>	5696.00	cm <sup>4</sup>
Moment of inertia	I <sub>z</sub>	2003.00	cm <sup>4</sup>
Governing radius of gyration	r <sub>y</sub>	85.40	mm
Governing radius of gyration	r <sub>z</sub>	50.70	mm
Polar radius of gyration	ro	99.30	mm
Radius of gyration of flange section plus $^{1}/_{5}$ of web area	r <sub>zg</sub>	53.90	mm



Volume	v	7808.00	cm³/m
Weight	wt	61.30	kg/m
Surface	A <sub>surf</sub>	1.15	m²/m
Section factor	A <sub>m</sub> /V	147.285	1/m
Torsional constant	J	59.28	cm <sup>4</sup>
Warping constant	C <sub>w</sub>	171,100.00	cm <sup>6</sup>
Elastic section modulus	Sy	569.60	cm <sup>3</sup>
Elastic section modulus	Sz	200.30	cm <sup>3</sup>
Warping section modulus	Ww	1849.73	cm <sup>4</sup>
Statical moment of area	Q <sub>y,max</sub>	321.25	cm <sup>3</sup>
Statical moment of area	Q <sub>z,max</sub>	75.00	cm <sup>3</sup>
Normalized warping constant	W <sub>no</sub>	92.50	cm <sup>2</sup>
Warping statical moment	Qw	693.75	cm <sup>4</sup>
Plastic section modulus	Zy	642.50	cm <sup>3</sup>
Plastic section modulus	Zz	305.80	cm <sup>3</sup>
Plastic warping section modulus	Zw	2775.00	cm <sup>4</sup>
Plastic shape factor	Z <sub>y/</sub> S <sub>y</sub>	1.128	
Plastic shape factor	Z <sub>z/</sub> S <sub>z</sub>	1.527	
Plastic shape factor	Z <sub>w/</sub> W <sub>w</sub>	1.500	

Table 8.1: Cross-section properties HE B 200

# Loading

Axial force	$N_{Ed}$	=	1000.00 kN
Moment	$M_{z,\text{Ed}}$	=	26.20 kNm
Moment	M <sub>y,Ed</sub>	=	34.50 kNm

4 Diubal

# 8.1.1 Check of Allowable Bending Moment in Top Flange

	A	B	С	D		E	1					F					
	Member	Location	Load	Des	sign												
No.	No.	x [m]	Case	Ratio						De	esign Accor	ding to Formula					
1	HEB 200																
	1	0.000	LC1					neck of shear flo		ge							
	1	0.000	LC1					neck of shear flo									
	1	0.000	LC1					neck of shear flo									
	1	0.000	LC1					neck of the allow									
	1	0.000	LC1					neck of the allow									
	1	0.000	LC1					neck of the minir									
	1	0.000	LC1					neck of the maxi									
	1	0.000	LC1									out the major axi					
	1	0.000	LC1		0.99	≤1	109) Ch	neck of the maxi	imum allowab	le bending	moment ab	out the major ax	S				
			Max:		0.99	≤1	۲					🗈 🛃 >	1.0	• 9	1 😂	🖪 🔇	3
	ial Propertie	- x: 0.000 m es - Steel S 2 operties - H Forces	235   DIN 18	800:1990-1	1								1 - HI	EB 200			
Materi     Cross     Cross     Desig     Desig     Ber     Rei     Pla	al Properti Section Pr n Internal F n Ratio nding mom duced yield stic axial ci stic bendin	es - Steel S 2 roperties - H	235   DIN 18 IEB 200 Inge about lo top flange f top flange	cal z-axis due to shear about local i	r and t z-axis			Mz, fo fy. τ. fo N pl, fo M pl, z, fo Mz, fo/M pl, z, fi	13.10 21.82 654.55 32.73 0.40	kN/cm <sup>2</sup> kN kNm	≤ 1.000		ŧ	EB 200	200.0	18.0	
Materi     Cross     Cross     Desig     Desig     Ber     Rei     Pla	al Properti Section Pr n Internal F n Ratio nding mom duced yield stic axial ci stic bendin	es - Steel S 2 operties - H Forces ent in top flar d strength of t apacity of top ig capacity of	235   DIN 18 IEB 200 Inge about lo top flange f top flange	cal z-axis due to shear about local i	r and t z-axis			f <sub>y,τ,fo</sub> Npl,fo Mpl,z,fo	21.82 654.55 32.73	kN/cm <sup>2</sup> kN kNm	≤ 1.000		1 - H	EB 200	200.0	18.0	
Materi Cross- Desig Desig Desig Ber Rei Pla Pla	al Properti Section Pr n Internal F n Ratio nding mom duced yield stic axial ci stic bendin	es - Steel S 2 operties - H Forces ent in top flar d strength of t apacity of top ig capacity of	235   DIN 18 IEB 200 Inge about lo top flange f top flange	cal z-axis due to shear about local i	r and t z-axis			f <sub>y,τ,fo</sub> Npl,fo Mpl,z,fo	21.82 654.55 32.73	kN/cm <sup>2</sup> kN kNm	≤ 1.000		ŧ	EB 200	200.0	18.0	

Figure 8.2: Check of the allowable bending moment at top flange

### **Material properties**

$$f_{y,d} = \frac{f_{y,k}}{\gamma_{M}} = \frac{24.00}{1.1} = \underline{21.82 \text{ kN/cm}^{2}}$$
$$\tau_{Rd} = \frac{f_{y,d}}{\sqrt{3}} = \underline{21.82} = \underline{12.60 \text{ kN/cm}^{2}}$$

### Partial internal forces in cross-section parts according to [1], Table 10.9

$$M_{t} = M_{b} = \frac{M_{z}}{2} - \frac{M_{\omega}}{a_{f}}$$
$$M_{t} = M_{b} = \frac{26.20}{2} - \frac{0}{(20.0 - 1.50)}$$
$$M_{t} = M_{b} = \underline{13.10 \text{ kNm}}$$

### Limiting plastic internal forces according to [1], Table 10.9

$$M_{pl,i,\tau} = \frac{t_{f} \cdot b^{2}}{4} \cdot f_{y,d} \cdot \sqrt{1 - \left(\frac{\tau_{i}}{\tau_{Rd}}\right)}$$
$$M_{pl,i,\tau} = \frac{1.50 \cdot 20.0^{2}}{4} \cdot 21.32 \cdot \sqrt{1 - (0)}$$
$$M_{pl,i,\tau} = \frac{3272.72 \text{ kNcm} = 32.73 \text{ kNm}}{4}$$
where i = 0, u



Check according to [1], Table 10.9

 $\frac{M_{i}}{M_{pl,i,\tau}} \le 1.00$  $\frac{13.10}{32.73} = \underbrace{0.40 \le 1.00}_{0.40}$ 

# 8.1.2 Check of the Allowable Axial Force

	A	B	С	D		E					F					
	Member	Location	Load	D	esign											
No.	No.	x [m]	Case	Rat	ю				[	Design Accor	ding to Formul	a				
1	HEB 200															
	1	0.000	LC1				Check of shear fl		je							
	1	0.000	LC1				Check of shear fl									
	1	0.000	LC1				Check of shear fl									
	1	0.000	LC1				Check of the allo									
	1	0.000	LC1				Check of the allo									
	1	0.000	LC1				Check of the mini									
	1	0.000	LC1				Check of the max									
	1	0.000	LC1				Check of the mini									
	1	0.000	LC1		0.99	≤ 1 109)	Check of the max	imum allowab	le bendin	g moment ab	out the major a	axis				
			Max:		0.99	≤1 🕑				[	D 🗐	> 1,0		7 😂	3	
		operties - Hi	-B 200													
	n Internal F		-B 200									_				
Desig	n Internal F n Ratio						N	-1000.00	kN			-		200.0		
Desig	n Internal F n Ratio sign axial fo	orces	ection	ocal z-axis			N Mz.fo	-1000.00 13.10					. †	200.0		
] Desig Desig Des	n Internal F n Ratio sign axial fo nding mome	orces	ection ge about k		ixis				kNm					200.0		
Desig Des Ber Ber	n Internal F n Ratio sign axial fo nding mome nding mome	orces orce in cross-s ent in top flan	ection ge about k flange abo	ut local z-a			M <sub>z,fo</sub>	13.10	kNm kNm					200.0	18.0	
Desig Des Ber Ber Pla	n Internal F n Ratio sign axial fo nding mome nding mome stic bending	orces orce in cross-s ent in top flan ent in bottom	ection ge about k flange abo top flange	ut local z-a about loca	al z-axis	pxis	M <sub>z,fo</sub> M <sub>z,fu</sub>	13.10 13.10	kNm kNm kNm				u u u u u u u u u u u u u u u u u u u	200.0	18.0	
Desig Des Ber Ber Pla Pla	n Internal F n Ratio sign axial fo nding mome nding mome stic bending stic bending	orces orce in cross-s ent in top flan ent in bottom f g capacity of	ection ge about lo flange abo top flange bottom flar	ut local z-a about loca	al z-axis	pxis	M <sub>z,fo</sub> M <sub>z,fu</sub> M <sub>pl,z,fo</sub>	13.10 13.10 32.73	kNm kNm kNm kNm			000		200.0	18.0	
] Desig Desig Ber Pla Pla Pla Pla	n Internal F n Ratio sign axial fo nding mome nding mome stic bending stic bending stic axial ca stic axial ca	orces orce in cross-s ent in top flam ent in bottom i g capacity of g capacity of apacity of top apacity of bott	ection ge about lo flange abo top flange bottom flar flange tom flange	ut local z-a about loca nge about	al z-axis	pdis	Mz, fo Mz, fu Mpl, z, fo Mpl, z, fu	13.10 13.10 32.73 32.73 654.55 654.55	kNm kNm kNm kN kN kN			200.0	C ur	200.0	18.0	
I Desig Desig Ber Ber Pla Pla Pla Pla Allo	n Internal F n Ratio sign axial for nding mome stic bendin stic bendin stic axial ca stic axial ca stic axial ca	orces orce in cross- ent in top flam ent in bottom i g capacity of g capacity of apacity of top apacity of bott I force in web	ection ge about lo lange abo top flange bottom flan flange tom flange	ut local z-a about loca nge about	al z-axis	pdis	Mz, fo Mz, fu Mpl,z, fo Mpl,z, fu Npl, fo	13.10 13.10 32.73 32.73 654.55 654.55 363.27	kNm kNm kNm kN kN kN kN			200.0	C S	200.0	18.0	
Desig Desig Ber Pla Pla Pla Pla Allo Allo	n Internal F n Ratio sign axial for nding mome stic bending stic bending stic axial ca stic axial ca stic axial ca stic axial ca stic axial ca	orces orce in cross-s ent in top flam ent in bottom i g capacity of g capacity of top apacity of top apacity of bott I force in web vable axial forc	ection ge about lo flange abo top flange bottom flange tom flange co in top fla	ut local z-a about loca nge about ange	al z-axis	odis	Mz, fo Mz, fu Mpl,z, fo Mpl,z, fu Npl, fo Npl, fu Nim, w Nim, min, fo	13.10 13.10 32.73 32.73 654.55 654.55 363.27 -506.89	kNm kNm kNm kN kN kN kN kN			200.0	C u v	200.0	18.0	-
) Desig Desig Ber Pla Pla Pla Pla Allo Min Min	n Internal F n Ratio sign axial fo nding mome stic bending stic bending stic axial ca stic axial ca wable axia imum allow imum allow	orces orce in cross-sent in top flam ent in bottom i g capacity of g capacity of top apacity of top apacity of bott I force in web vable axial forr vable axial forr	ection ge about lo flange abo top flange bottom flan flange com flange com flange com flange	ut local z-a about loca nge about ange m flange	al z-axis	pds	Mz, fo Mz, fu Mpl,z, fo Mpl,z, fu Npl, fo Npl, fu Nim, w Nim, min, fo	13.10 13.10 32.73 32.73 654.55 654.55 363.27 -506.89 -506.89	kNm kNm kNm kN kN kN kN kN kN kN			200:0		200.0	18.0	-
I Desig Desig Ber Pla Pla Pla Pla Allo Min Min Min	n Internal F n Ratio sign axial fo ding mome ding mome stic bendin stic bendin stic axial ca stic axial ca wable axia imum allow imum allow	Forces arce in cross-s- ent in top flam- ent in bottom i g capacity of g capacity of top apacity of bott il force in web vable axial forr vable axial forr	ection ge about lo flange abo top flange bottom flange tom flange ce in top fla ce in top fla ce in botto ce in cross	ut local z-a about loca nge about ange mflange -section	al z-axis local z-a		Mz, fo Mz, fu Mpl,z, fo Mpl,z, fu Npl, fo Npl, fu Nim, min, fo Niim, min, fu Niim, min	13.10 13.10 32.73 32.73 654.55 654.55 363.27 -506.89 -506.89 -1377.06	kNm kNm kNm kN kN kN kN kN kN kN			200.0	C u	200.0		- •
I Desig Desig Ber Pla Pla Pla Pla Allo Min Min Min	n Internal F n Ratio sign axial fo ding mome ding mome stic bendin stic bendin stic axial ca stic axial ca wable axia imum allow imum allow	Forces arce in cross-s- ent in top flam- ent in bottom i g capacity of g capacity of top apacity of bott il force in web vable axial forr vable axial forr	ection ge about lo flange abo top flange bottom flange tom flange ce in top fla ce in top fla ce in botto ce in cross	ut local z-a about loca nge about ange mflange -section	al z-axis local z-a		Mz, fo Mz, fu Mpl,z, fo Mpl,z, fu Npl, fo Npl, fu Nim, w Nim, min, fo	13.10 13.10 32.73 32.73 654.55 654.55 363.27 -506.89 -506.89	kNm kNm kNm kN kN kN kN kN kN kN	≤ 1.000		200:0 5		200.0		-
Desig Des Ber Pla Pla Pla Pla Allo Min Min	n Internal F n Ratio sign axial fo ding mome ding mome stic bendin stic bendin stic axial ca stic axial ca wable axia imum allow imum allow	Forces arce in cross-s- ent in top flam- ent in bottom i g capacity of g capacity of top apacity of bott il force in web vable axial forr vable axial forr	ection ge about lo flange abo top flange bottom flange tom flange ce in top fla ce in top fla ce in botto ce in cross	ut local z-a about loca nge about ange mflange -section	al z-axis local z-a		Mz, fo Mz, fu Mpl,z, fo Mpl,z, fu Npl, fo Npl, fu Nim, min, fo Niim, min, fu Niim, min	13.10 13.10 32.73 32.73 654.55 654.55 363.27 -506.89 -506.89 -1377.06	kNm kNm kNm kN kN kN kN kN kN kN	≤ 1.000		200.0		200.0		
I Desig Desig Ber Pla Pla Pla Pla Allo Min Min Min	n Internal F n Ratio sign axial fo ding mome ding mome stic bendin stic bendin stic axial ca stic axial ca wable axia imum allow imum allow	Forces arce in cross-s- ent in top flam- ent in bottom i g capacity of g capacity of top apacity of bott il force in web vable axial forr vable axial forr	ection ge about lo flange abo top flange bottom flange tom flange ce in top fla ce in top fla ce in botto ce in cross	ut local z-a about loca nge about ange mflange -section	al z-axis local z-a		Mz, fo Mz, fu Mpl,z, fo Mpl,z, fu Npl, fo Npl, fu Nim, min, fo Niim, min, fu Niim, min	13.10 13.10 32.73 32.73 654.55 654.55 363.27 -506.89 -506.89 -1377.06	kNm kNm kNm kN kN kN kN kN kN kN	≤ 1.000		200.0		200.0	<u>18.0</u>	-
Desig Desig Ber Pla Pla Pla Pla Allo Min Min Min	n Internal F n Ratio sign axial fo ding mome ding mome stic bendin stic bendin stic axial ca stic axial ca wable axia imum allow imum allow	Forces arce in cross-s- ent in top flam- ent in bottom i g capacity of g capacity of top apacity of bott il force in web vable axial forr vable axial forr	ection ge about lo flange abo top flange bottom flange tom flange ce in top fla ce in top fla ce in botto ce in cross	ut local z-a about loca nge about ange mflange -section	al z-axis local z-a		Mz, fo Mz, fu Mpl,z, fo Mpl,z, fu Npl, fo Npl, fu Nim, min, fo Niim, min, fu Niim, min	13.10 13.10 32.73 32.73 654.55 654.55 363.27 -506.89 -506.89 -1377.06	kNm kNm kNm kN kN kN kN kN kN kN	≤ 1.000		20020		200.0	<u>18.0</u>	- <b>•</b>

Figure 8.3: Check of the allowable axial forces

Limiting plastic internal forces according to [1], Table 10.8

$$\begin{split} N_{lim,i} &= t_{f} \cdot b \cdot f_{y,d} \cdot \sqrt{1 - \left(\frac{\tau_{i}}{\tau_{Rd}}\right) \cdot \sqrt{1 - \left(\frac{M_{i}}{M_{pl,i,\tau}}\right)}} \\ N_{lim,i} &= 1.50 \cdot 20.0 \cdot 21.32 \cdot \sqrt{1 - 0} \cdot \sqrt{1 - 0.40} \\ N_{lim,i} &= \frac{506.89 \text{ kN}}{1 - \left(\frac{\tau_{s}}{\tau_{Rd}}\right)^{2}} \\ where i &= o, u \\ N_{lim,w} &= t_{w} \cdot h_{w} \cdot f_{y,d} \cdot \sqrt{1 - \left(\frac{\tau_{s}}{\tau_{Rd}}\right)^{2}} \\ N_{lim,w} &= 0.9 \cdot (20.0 - 1.50) \cdot 21.32 \cdot \sqrt{1 - 0^{2}} \\ N_{lim,w} &= \frac{363.27 \text{ kN}}{1 - \left(\frac{1}{1 - 1}\right)^{2}} \\ N_{lim} &= 506.89 + 506.89 + 363.27 \\ N_{lim} &= \frac{1377.06 \text{ kN}}{1 - 1 - 1} \end{split}$$



### Check

 $\frac{N}{N_{lim}} \le 1.00$  $\frac{1000}{1377.06} = \underbrace{0.73 \le 1.00}_{1.00}$ 

## 8.1.3 Check of the Allowable Bending Moment

	A	B	С	D	E						F			
ection	Member	Location	Load	Design										
No.	No.	x [m]	Case	Ratio					1	Design Acco	rding to Formula			
1	HEB 200													
	1	0.000	LC1				neck of shear flo		е					
	1	0.000	LC1				neck of shear flo							
	1	0.000	LC1				neck of shear flo							
	1	0.000	LC1				neck of the allow							
	1	0.000	LC1				neck of the allow							
	1	0.000	LC1				neck of the mini							
	1	0.000	LC1				neck of the max							
	1	0.000	LC1								out the major axis			
	1	0.000	LC1	0.99	≤1	109) Ci	neck of the max	imum allowabl	e bendin	g moment ab	out the major axi	s		
			Max:	0.99	≤1	۲					黤 ⋤ >	1,0	•	😂 🛐 🍾
Design	Section Pro n Internal F n Ratio	operties - Hi orces	EB 200											
		rce in cross-s	ection				N	-1000.00	kN					200.0
Des	sign bendin	g moment in	cross-secti	on about major ax	dis		Mv	34.50	kNm				Ι.	I
		force in web		-			Nim.w	363.27	kN					ullinnnn
Min	imum allow	able axial for	ce in top fla	ange			N lim, min, fo	-506.89	kN				15.0	18.0
Max	kimum allow	able axial for	ce in top fl	ange			N lim, max, fo	506.89	kN					
		able axial for					N lim, min, fu	-506.89				200.0		S
		rable axial for					N lim, max, fu	506.89				~		
		able axial for		000000			N lim, min	-1377.06						9.0
		rable axial for					N lim, max	1377.06						
				bout local major a			My,min	-34.88	kNm		[1] : Tab. 10.1	+		
Rat	io of desigr	n bending mo	ment abou	t major axis to mir	imum	allował	My/My,min	0.99		≤ 1.000				÷
														z

Figure 8.4: Design of the allowable bending moment about major axis

### Governing case according to [1], Table 10.8

Case 3:

$$\begin{split} & N_{lim} - 2 \cdot N_{lim,b} \leq N \leq N_{lim} \\ & 1377.06 - 2 \cdot 506.89 \leq 1000.00 \leq 1377.06 \\ & 363.28 \leq 1000.00 \leq 1377.06 \implies OK \end{split}$$

### Limiting plastic internal forces [1], Table 10.8

 $\max M_{y} = (2 \cdot N_{\lim,b} + N_{\lim,w} - N) \cdot \frac{a_{f}}{2}$  $\max M_{y} = (2 \cdot 506.89 + 363.27 - 1000.00) \cdot \frac{0.20 - 0.015}{2}$  $\max M_{y} = \underline{34.877 \text{ kNm}}$ 

### Check according to [1], Table 10.8

 $\frac{M_{y}}{\max M_{y}} \le 1.00$  $\frac{34.50}{34.88} = \underbrace{0.99 \le 1.00}$ 



# 8.2 Monosymmetrical I-Section

The following example is presented in [1], page 190 f. The interaction from double-bending with shear force but without taking account of bimoment  $M_{\omega}$  is analyzed.

### **Cross-Section**

Monosymmetrical I-Section IU 432/300/20/12/180/12

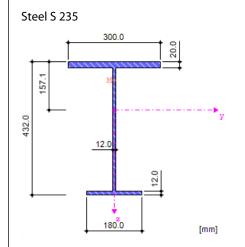


Figure 8.5: Monosymmetrical I-Section IU 432/300/20/12/180/12

### **Cross-section properties**

Cross-section property	Symbol	Value	Unit
Depth	h	432.000	mm
Upper flange width	bt	300.000	mm
Upper flange thickness	tt	20.000	mm
Web thickness	s	12.000	mm
Lower flange width	b <sub>b</sub>	180.000	mm
Lower flange thickness	t <sub>b</sub>	12.000	mm
Upper fillet web thickness	at	6.000	mm
Lower fillet web thickness	a <sub>b</sub>	6.000	mm
Cross-sectional area	А	129.600	cm <sup>2</sup>
Shear area	Ay	81.600	cm <sup>2</sup>
Shear area	Az	48.000	cm <sup>2</sup>
Distance to center of gravity	ez	157.100	mm
Moment of inertia	l <sub>y</sub>	36,923.100	cm <sup>4</sup>
Moment of inertia	Iz	5088.960	cm <sup>4</sup>
Polar moment of inertia	Ip	42,012.000	cm <sup>4</sup>
Polar moment of inertia	I <sub>p,M</sub>	54,783.600	cm <sup>4</sup>
Moment of inertia referred to the smaller flange	I <sub>y,SF</sub>	37,271.600	cm <sup>4</sup>
Governing radius of gyration	r <sub>y</sub>	168.800	mm
Governing radius of gyration	r <sub>z</sub>	62.700	mm
Polar radius of gyration	ro	180.000	mm
Polar radius of gyration	r <sub>p,M</sub>	205.700	mm
Weight	wt	101.700	kg/m

Dlub	al

Surface	A <sub>surf</sub>	1.800	m²/m
Torsional constant	J	110.530	cm <sup>4</sup>
Distance from the shear center to the center of			
gravity S	ZM	-99.300	mm
Warping constant referring to M	Cw	893,470.000	cm <sup>6</sup>
Fade factor	λ	0.001	1/mm
Elastic section modulus	S <sub>y,max</sub>	1343.200	cm <sup>3</sup>
Elastic section modulus	S <sub>y,min</sub>	-2350.120	cm <sup>3</sup>
Elastic section modulus	Sz	339.260	cm <sup>3</sup>
Warping section modulus	Ww	2696.510	cm⁴
Statical moment of area	Q <sub>y,max</sub>	995.460	cm <sup>3</sup>
Statical moment of area	Q <sub>z,max</sub>	224.910	cm <sup>3</sup>
Normalized warping constant	W <sub>no</sub>	331.340	cm <sup>2</sup>
Warping statical moment	Qw	1789.250	cm <sup>4</sup>
Stability parameter according to Kindem	r <sub>y,Kindem</sub>	87.000	mm
Stability parameter	r <sub>M,z</sub>	285.500	mm
Location of area center line	fz	-97.100	mm
Plastic section modulus	Zy	1877.760	cm <sup>3</sup>

Table 8.2: Cross-section properties IU 432/300/20/12/180/12

## **Material properties**

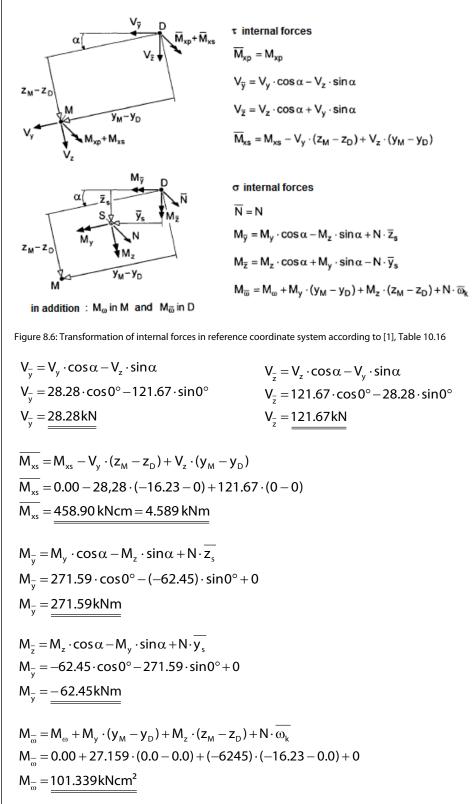
$$f_{y,d} = \frac{f_{y,k}}{\gamma_{M}} = \frac{24.00}{1.1} = \underbrace{\frac{21.82 \text{ kN/cm}^{2}}{1.1}}_{\tau_{Rd}} = \frac{f_{y,d}}{\sqrt{3}} = \underbrace{\frac{21.82}{\sqrt{3}}}_{\frac{12.60 \text{ kN/cm}^{2}}{1.1}}$$

# Loading

Shear force	$V_{\text{z,Ed}}$	=	121.67 kN
Shear force	$V_{\text{y,Ed}}$	=	28.28 kN
Moment	$M_{z,\text{Ed}}$	=	-62.45 kNm
Moment	$M_{\text{y,Ed}}$	=	271.59 kNm



### 8.2.1 Transformation of Internal Forces





# 8.2.2 Shear Resistance in Top Flange

_	A	B	С	D	E						F	_	_			_
Section		Location	Load	Design	-											
No.	No.	x [m]	Case	Ratio					De	esign Acco	rding to Formul	la				
1	IU 432/3	00/20/12/18	0/12/6/6													
	1	0.000	LC1	0.03	≤1	101) Check	of shear flow in top	flang	je							
	1	0.000	LC1				of shear flow in we									
	1	0.000	LC1				of shear flow in bot									
	1	0.001	LC1				of the acceptable									
	1	0.001	LC1				of the acceptable									
	1	0.000	LC1				of the minimum ac									
	1	0.000	LC1				of the maximum ac									
	1	0.001	LC1				of the minimum ac									
	1	0.001	LC1	0.80	≤1	109) Check	of the maximum ac	cepta	ible bendin	g moment :	about the majo	r axis				
			Max:	0.80	≤1	3					🔋 🛐	> 1.0	-	7 🔮	1 🖪 🐧	8
± Cross	-Section Va			0:1990-11 /12/180/12/6/6								- 1-	10 4325	300/20/12/	180/12/6/6	
∃ Cross ∃ Desig ∃ Desig	-Section Va In Internal F In Ratio	alues - IU 43 Forces										-	10 4325	300/20/12/	180/12/6/6	
± Cross ± Desig ⊒ Desig To	-Section Va In Internal F In Ratio p flange yie	alues - IU 43 Forces	32/300/20/			f <sub>y,t</sub>	-		kN/cm <sup>2</sup>				10 4325	300/20/1 2/		
	-Section Va n Internal F n Ratio p flange yie p flange yie	alues - IU 43 Forces Id strength	32/300/20/			fy,	τ.fo 1	2.60	kN/cm <sup>2</sup>				10 4325			
± Cross ± Desig ∃ Desig To To To To	-Section Va In Internal F In Ratio In Ratio In Ratio In Ratio In International Figure Participation International Figure Participation Internation Participation Internation Internation Internation Internatio Interna	alues - IU 43 Forces Id strength Id strength in ulus of top fla	shear	/12/180/12/6/6		fy, It,f	τ.fo 1 fo 7	2.60 76.64	kN/cm <sup>2</sup> cm <sup>4</sup>			1-	+ +		20.0	
E Cross     Desig     Desig     Tol     Tol     Tol     Tol     Tol     Prir	-Section Va n Internal F n Ratio p flange yie p flange yie rsional mod mary torsion	alues - IU 43 Forces Id strength Id strength in ulus of top fla nal moment wi	shear ange ith respect	/12/180/12/6/6 to web center		fy, It,f Tp	τ,fo 1 fo 7 rim	2.60 6.64 0.00	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm				157.1			
	-Section Va n Internal F n Ratio p flange yie p flange yie rsional mod mary torsion condary tor	alues - IU 43 Forces Id strength Id strength in ulus of top fla nal moment wi sional moment	shear ange ith respect at with resp	12/180/12/6/6 to web center ect to web center		fy, IT,f Tpr Tse	τ, fo 1 fo 7 rim ec 45	2.60 6.64 0.00 8.59	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm				157.1		20.0	•
Tross     Top     Top	-Section Va n Internal F n Ratio p flange yie p flange yie rsional mod mary torsion condary tor p flange sho	alues - IU 43 Forces Id strength Id strength in ulus of top fla nal moment wi sional momen ear force in lo	shear ange ith respect at with resp ocal y-direct	12/180/12/6/6 to web center ect to web center tion		fy, IT,f Tpr Tse Vy	τ, fo 1 to 7 rim ec 45 ,fo 2	2.60 6.64 0.00 8.59 5.03	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN			- 1 - 432.0	157.1			•
Tross     Top     Top	-Section Va p Internal F p Ratio p flange yie p flange yie rsional mod mary torsion condary tors p flange shi p flange pla	alues - IU 43 Forces Id strength Id strength in ulus of top fla nal moment wi sional momen ear force in lo astic shear ca	shear ange ith respect at with resp ocal y-direct ipacity in lo	to web center ect to web center ion cal y-direction		Гу, Гт, Тр Тя Уу Vy Vp	τ, fo 1 to 7 rim 2 ec 45 ,fo 2 I,y,fo 75	2.60 76.64 0.00 8.59 5.03 5.80	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN kN				157.1	300.0	20.0	
Cross     Cross     Desig     Desig     Top	-Section Va p Internal F p Ratio p flange yie p flange yie rsional mod mary torsion condary tors p flange shi p flange pla mary torsion	alues - IU 43 orces Id strength Id strength in ulus of top fla nal moment wi sional momen ear force in lo astic shear ca nal moment in	shear ange ith respect at with resp ocal y-direct pacity in lo top flange	to web center ect to web center ion cal y-direction		Гу, Гт, Тр Тя Уу Vу Vр Тр	r, fo 1 fo 7 fim 2 ec 45 , fo 2 l.y. fo 75 fim, fo 75	2.60 76.64 0.00 8.59 5.03 5.80 0.00	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN				157.1	300.0		•
Cross     Cross     Toisig     Toi     Toi     Toi     Prir     Sei     Toi     Prir     Prir     Pla	-Section Va n Internal F n Ratio p flange yie p flange yie rsional mod mary torsion condary tor p flange shi p flange pla mary torsion istic torsion	alues - IU 43 Forces Id strength Id strength in ulus of top fla nal moment wi sional momen ear force in lo astic shear ca	shear ange ith respect at with resp ocal y-direct pacity in lo top flange	to web center ect to web center ion cal y-direction		Гу, Гт, Тр Тя Уу Vy Vp	r, fo 1 r fo 7 rim ec 45 , fo 2 l, y, fo 75 rim, fo 75 rim, fo 73	2.60 76.64 0.00 8.59 5.03 5.80 0.00 0.61	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN kN kN				157.1	300.0		+
Tross     Cross     Top     Top	-Section Va n Internal F n Ratio p flange yie p flange yie rsional mod mary torsion condary tor p flange pla p flange pla mary torsion istic torsion ear stress ir	alues - IU 43 Forces Id strength Id strength in ulus of top fla nal moment wi sional moment ear force in lo ustic shear ca al moment in al capacity of top flange	shear ange ith respect nt with resp ccal y-direct pacity in lo top flange	to web center ect to web center ion cal y-direction		fy.  T <sub>1</sub> , T <sub>p</sub> T <sub>s</sub> V <sub>y</sub> V <sub>p</sub> T <sub>p</sub> T <sub>p</sub> T <sub>p</sub>	r. fo 1 fo 7 nim 8 80 45 .fo 2 Ly, fo 75 nim, fo 73	2.60 76.64 0.00 8.59 5.03 5.80 0.00 0.61	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN kN kNcm kNcm	≤1.000			157.1	300.0		•
Tross     Cross     Top     Top	-Section Va n Internal F n Ratio p flange yie p flange yie rsional mod mary torsion condary tor p flange pla p flange pla mary torsion istic torsion ear stress ir	alues - IU 43 Forces Id strength Id strength in ulus of top fla nal moment wi sional moment ear force in lo ustic shear ca al moment in al capacity of top flange	shear ange ith respect nt with resp ccal y-direct pacity in lo top flange	12/180/12/6/6 to web center ect to web center ion cal y-direction		fy.  T <sub>1</sub> , T <sub>p</sub> T <sub>s</sub> V <sub>y</sub> V <sub>p</sub> T <sub>p</sub> T <sub>p</sub> T <sub>p</sub>	r. fo 1 fo 7 nim 8 80 45 .fo 2 Ly, fo 75 nim, fo 73	2.60 76.64 0.00 8.59 5.03 5.80 0.00 0.61 0.42	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN kN kNcm kNcm	≤ 1.000			157.1	300.0		
Tross     Cross     Top     Top	-Section Va n Internal F n Ratio p flange yie p flange yie rsional mod mary torsion condary tor p flange pla p flange pla mary torsion istic torsion ear stress ir	alues - IU 43 Forces Id strength Id strength in ulus of top fla nal moment wi sional moment ear force in lo ustic shear ca al moment in al capacity of top flange	shear ange ith respect nt with resp ccal y-direct pacity in lo top flange	12/180/12/6/6 to web center ect to web center ion cal y-direction		fy.  T <sub>1</sub> , T <sub>p</sub> T <sub>s</sub> V <sub>y</sub> V <sub>p</sub> T <sub>p</sub> T <sub>p</sub> T <sub>p</sub>	r. fo 1 fo 7 nim 8 80 45 .fo 2 Ly, fo 75 nim, fo 73	2.60 76.64 0.00 8.59 5.03 5.80 0.00 0.61 0.42	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN kN kNcm kNcm	≤ 1.000			157.1	300.0		*
Tross     Cross     Top     Top	-Section Va n Internal F n Ratio p flange yie p flange yie rsional mod mary torsion condary tor p flange pla p flange pla mary torsion istic torsion ear stress ir	alues - IU 43 Forces Id strength Id strength in ulus of top fla nal moment wi sional moment ear force in lo ustic shear ca al moment in al capacity of top flange	shear ange ith respect nt with resp ccal y-direct pacity in lo top flange	12/180/12/6/6 to web center ect to web center ion cal y-direction		fy.  T <sub>1</sub> , T <sub>p</sub> T <sub>s</sub> V <sub>y</sub> V <sub>p</sub> T <sub>p</sub> T <sub>p</sub> T <sub>p</sub>	r. fo 1 fo 7 nim 8 80 45 .fo 2 Ly, fo 75 nim, fo 73	2.60 76.64 0.00 8.59 5.03 5.80 0.00 0.61 0.42	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN kN kNcm kNcm	≤ 1.000			157.1	300.0		•
Tross     Cross     Top     Top	-Section Va n Internal F n Ratio p flange yie p flange yie rsional mod mary torsion condary tor p flange pla p flange pla mary torsion istic torsion ear stress ir	alues - IU 43 Forces Id strength Id strength in ulus of top fla nal moment wi sional moment ear force in lo ustic shear ca al moment in al capacity of top flange	shear ange ith respect nt with resp ccal y-direct pacity in lo top flange	12/180/12/6/6 to web center ect to web center ion cal y-direction		fy.  T <sub>1</sub> , T <sub>p</sub> T <sub>s</sub> V <sub>y</sub> V <sub>p</sub> T <sub>p</sub> T <sub>p</sub> T <sub>p</sub>	r. fo 1 fo 7 nim 8 80 45 .fo 2 Ly, fo 75 nim, fo 73	2.60 76.64 0.00 8.59 5.03 5.80 0.00 0.61 0.42	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN kN kNcm kNcm	≤ 1.000			157.1	300.0		•
Tross     Cross     Top     Top	-Section Va n Internal F n Ratio p flange yie p flange yie rsional mod mary torsion condary tor p flange pla p flange pla mary torsion istic torsion ear stress ir	alues - IU 43 Forces Id strength Id strength in ulus of top fla nal moment wi sional moment ear force in lo ustic shear ca al moment in al capacity of top flange	shear ange ith respect nt with resp ccal y-direct pacity in lo top flange	12/180/12/6/6 to web center ect to web center ion cal y-direction		fy.  T <sub>1</sub> , T <sub>p</sub> T <sub>s</sub> V <sub>y</sub> V <sub>p</sub> T <sub>p</sub> T <sub>p</sub> T <sub>p</sub>	r. fo 1 fo 7 nim 8 80 45 .fo 2 Ly, fo 75 nim, fo 73	2.60 76.64 0.00 8.59 5.03 5.80 0.00 0.61 0.42	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN kN kNcm kNcm	≤ 1.000			157.1	300.0		•

Figure 8.7: Check of shear resistance in top flange

### Partial internal forces in cross-section parts according to [1], Table 10.17

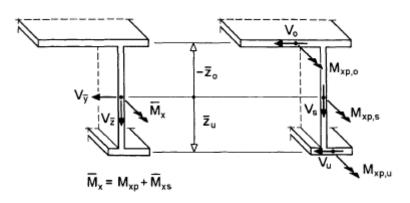


Figure 8.8: Internal forces  $\tau$  in cross-section consisting of three plates acc. to Figure 10.40 [1]

$$V_{t} = \frac{\left(V_{\overline{y}} \cdot \overline{z}_{b} + \overline{M}_{xs}\right)}{\left(\overline{z}_{b} - \overline{z}_{t}\right)}$$
$$V_{t} = \frac{\left(28.28 \cdot 0.206 + 4.589\right)}{\left((0.206 + 0.21\right)}$$
$$V_{t} = \underline{25.04 \text{ kN}}$$

#### Limiting plastic internal forces according to [1], Table 10.17

$$V_{pl,t} = \tau_{Rd} \cdot b_{t} \cdot t_{t} \qquad M_{xp,t} = M_{xp} \cdot \frac{I_{T,t}}{I_{T}}$$

$$V_{pl,t} = 12.60 \cdot 30.0 \cdot 2.0 \qquad M_{xp,t} = M_{xp} \cdot \frac{I_{T,t}}{I_{T}}$$

$$V_{pl,t} = \underline{755.80 \text{ kN}} \qquad M_{xp,t} = \underline{0.00 \text{ kNm}}$$

$$M_{pl,xp,t} = \frac{\tau_{Rd} \cdot t_{t}^{2} \cdot (2 \cdot b_{t} - t_{t})}{4}$$

$$M_{pl,xp,t} = \frac{12.60 \cdot 2.0^{2} \cdot (2 \cdot 30.0 - 2.0)}{4}$$

$$M_{pl,xp,t} = \underline{730.61 \text{ kNcm}}$$

### Check according to [1], Table 10.17

$$\begin{aligned} \tau_{t} &= \frac{\left| \mathsf{M}_{xp,t} \right|}{2 \cdot \mathsf{M}_{pl,xp,t}} + \sqrt{\left( \frac{\mathsf{M}_{xp,t}}{2 \cdot \mathsf{M}_{pl,xp,t}} \right)^{2} + \left( \frac{\mathsf{V}_{t}}{\mathsf{V}_{pl,t}} \right)^{2}} \cdot \frac{\mathsf{f}_{y,d}}{\sqrt{3}} \\ \tau_{t} &= \frac{\left| 0.00 \right|}{2 \cdot 730.61} + \sqrt{\left( \frac{0.00}{2 \cdot 730.61} \right)^{2} + \left( \frac{25.04}{755.80} \right)^{2}} \cdot \frac{\mathsf{f}_{y,d}}{\sqrt{3}} = \underline{0.417 \, \text{kN/cm}^{2}} \\ \Rightarrow & \frac{\tau_{t}}{\tau_{\text{Rd}}} = \underline{0.03 \le 1.00} \end{aligned}$$

## 8.2.3 Shear Resistance in Web

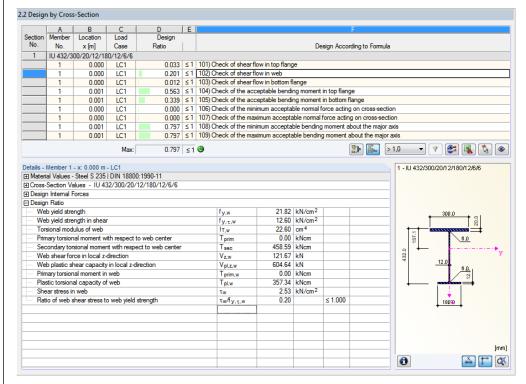


Figure 8.9: Check of shear resistance in web



### Partial internal forces in cross-section parts according to [1], Table 10.17

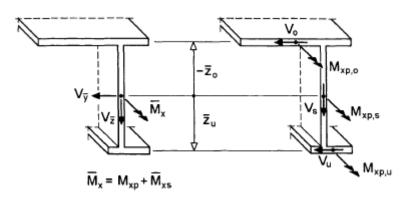


Figure 8.10: Partial internal forces  $\tau$  in cross-section consisting of three plates according to Figure 10.40 [1]

 $V_{w} = V_{z}^{-}$  $V_{w} = \underline{121.67 \text{ kN}}$ 

### Limiting plastic internal forces according to [1], Table 10.17

$V_{pl,w} = \tau_{Rd} \cdot \mathbf{h}_{w} \cdot \mathbf{t}_{w}$ $V_{pl,w} = 12.60 \cdot 40.0 \cdot 1.2$	$\mathbf{M}_{xp,w} = \mathbf{M}_{xp} \cdot \frac{\mathbf{I}_{\mathrm{T},w}}{\mathbf{I}_{\mathrm{T}}}$
$V_{pl,w} = 604.64 \text{ kN}$	$M_{xp,w} = \underbrace{0.00 \text{ kNm}}_{m}$
$M_{pl,xp,w} = \frac{\tau_{Rd} \cdot t_w^2 \cdot (2 \cdot h_w - t_w)}{4}$	
$M_{pl,xp,w} = \frac{12.60 \cdot 1.2^2 \cdot (2 \cdot 40.0 - 1.2)^2}{4}$	.2)
$M_{pl,xp,w} = 357.34 \text{ kNcm}$	

$$\tau_{s} = \frac{\left|M_{xp,w}\right|}{2 \cdot M_{pl,xp,w}} + \sqrt{\left(\frac{M_{xp,w}}{2 \cdot M_{pl,xp,w}}\right)^{2} + \left(\frac{V_{w}}{V_{pl,w}}\right)^{2} \cdot \frac{f_{y,d}}{\sqrt{3}}} \\ \tau_{s} = \frac{\left|0,00\right|}{2 \cdot 357.34} + \sqrt{\left(\frac{0.00}{2 \cdot 357.34}\right)^{2} + \left(\frac{121.67}{604.64}\right)^{2}} \cdot \frac{f_{y,d}}{\sqrt{3}} = \underbrace{2.54 \text{ kN/cm}^{2}}_{\Rightarrow} \frac{\tau_{w}}{\tau_{Rd}} = \underbrace{0.20 \le 1.00}_{=}$$



# 8.2.4 Shear Resistance in Bottom Flange

	A	B	С	D	I E						F		_		_	
Section	Member	Location	Load	Design												
No.	No.	x [m]	Case	Ratio					De	esign Acco	rding to Formul	а				
1	IU 432/3	00/20/12/18	0/12/6/6													
	1	0.000	LC1				eck of shear flow		je							
	1	0.000	LC1				eck of shear flov									
	1	0.000	LC1				eck of shear flov									
	1	0.001	LC1				eck of the accept									
	1	0.001	LC1				eck of the acce									
	1	0.000	LC1				eck of the minim									
	1	0.000	LC1				eck of the maxin									
	1	0.001	LC1				eck of the minim									
	1	0.001	LC1	0.797	≤1	109) Ch	eck of the maxin	num accepta	able bendin	g moment a	about the majo	raxis				
			Max:	0.797	<1	۲					🗈 🖪	> 1.0	-		2 🔍	<b>N</b>
∃ Mater ∃ Cross	ial Values - -Section Va		DIN 1880	D:1990-11 12/180/12/6/6								1 -	IU 432)	300/20/12	/180/12/6/	6
∃ Mater ∃ Cross ∃ Desig	ial Values - -Section Va n Internal F	Steel S 235   alues - IU 43	DIN 1880									1-	IU 432/	300/20/12	/180/12/6/	6
∃ Mater ∃ Cross ∃ Desig ∃ Desig	ial Values - -Section Va n Internal F n Ratio	Steel S 235   alues - IU 43	DIN 1880				fy,fu	21.82	kN/cm <sup>2</sup>			1 -	IU 432/	300/20/12	0	-
E Mater E Cross E Desig Desig Bot	ial Values - -Section Va n Internal F n Ratio ttom flange	Steel S 235   alues - IU 43 orces	DIN 18800				fy,fu fy,τ,fu	12.60	kN/cm <sup>2</sup>			1 -	IU 432/			-
Mater     Cross     Desig     Desig     Desig     Bot     Bot	ial Values - -Section Va n Internal F n Ratio ttom flange ttom flange	Steel S 235   alues - IU 43 Forces yield strength	DIN 1880 2/300/20/						kN/cm <sup>2</sup>			1 -	•••		0	-
Mater Cross Desig Desig Desig Bot Bot Tor	ial Values - -Section Va n Internal F n Ratio ttom flange ttom flange rsional mod mary torsion	Steel S 235   alues - IU 43 orces yield strength yield strength ulus of bottom al moment wi	DIN 1880 2/300/20/ in in shear in flange th respect f	to web center			fy fu	12.60 9.93	kN/cm <sup>2</sup>			1 -	IU 432/			-
Mater ☐ Cross ☐ Desig ☐ Desig ☐ Desig Bot Bot Tor Prir Sec	ial Values - -Section Va n Internal F n Ratio ttom flange rsional mod mary torsion condary tor	Steel S 235   alues - IU 43 orces yield strength yield strength ulus of botton al moment wi sional momen	DIN 1880 2/300/20/ in shear n flange th respect to it with respect to	to web center ect to web center			fy.τ.fu IT,fu	12.60 9.93 0.00 458.59	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm				157.1			-
Mater  Mater  Cross  Desig  Desig  Bot  Bot  Tor  Prir  See  Bot	ial Values - -Section Va n Internal F n Ratio ttom flange ttom flange rsional mod mary torsion condary tor ttom flange	Steel S 235   alues - IU 43 forces yield strength yield strength ulus of botton hal moment wi sional momen shear force in	DIN 1880 2/300/20/ in shear in flange th respect to it with response n local y-dim	to web center ect to web center ection			Γ <sub>y.τ.fu</sub> I <sub>T.fu</sub> T <sub>prim</sub> T <sub>sec</sub> V <sub>y.fu</sub>	12.60 9.93 0.00 458.59 3.25	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN			- 1 -	157.1	300		-
Mater     Mater     Cross     Desig     Desig     Desig     Bot     Tor     Prir     Sec     Bot     Bot	ial Values - -Section Va n Internal F n Ratio ttom flange ttom flange rsional mod mary torsion condary tor ttom flange ttom flange	Steel S 235   alues - IU 43 forces yield strength yield strength ulus of botton hal moment wi sional momen shear force in plastic shear	DIN 1880 2/300/20/ in in shear in flange th respect f it with respect n local y-din capacity in	12/180/12/6/6 to web center act to web center ection local y-direction			Гу.т.fu IT,fu T prim T sec Vy.fu Vpl,y,fu	12.60 9.93 0.00 458.59 3.25 272.09	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN kN				157.1			-
Mater     Mater     Cross     Desig     Desig     Desig     Bot     Bot     Tor     Prir     Sec     Bot     Bot     Prir	ial Values - -Section Va n Internal F n Ratio ttom flange trom flange rsional mod mary torsion condary tor ttom flange mary torsion	Steel S 235   alues - IU 43 orces yield strength yield strength ulus of botton hal moment wi sional moment shear force in plastic shear hal moment in	DIN 18800 2/300/20/ in shear n flange th respect to the with respect n local y-din capacity in bottom flan	12/180/12/6/6 to web center ect to web center ection local y-direction ige			fy.τ.fu           IT.fu           Tprim           Tsec           Vy.fu           Vpl.y.fu           Tprim, fu	12.60 9.93 0.00 458.59 3.25 272.09 0.00	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN kN kN				157.1	300		-
Mater Cross Desig Desig Bot Bot Prir Bot Bot Prir Pla	al Values - -Section Va n Internal F n Ratio ttom flange ttom flange transional mod mary torsion condary tor tom flange mary torsion stic torsion	Steel S 235   alues - IU 43 orces yield strength yield strength ulus of botton al moment wi sional moment shear force ir plastic shear al moment in al capacity of	DIN 1880 2/300/20/ in in shear in flange th respect to the with respect in local y-dir capacity in bottom flar bottom flar	12/180/12/6/6 to web center ect to web center ection local y-direction ige			fy,τ,fu           IT,fu           Tprim           Tsec           Vy,fu           Vpl,y,fu           Tprim,fu           Tpl,fu	12.60 9.93 0.00 458.59 3.25 272.09 0.00 157.81	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN kN kNcm kNcm				157.1	300		-
Mater Cross Cross Desig Desig Desig Bot Bot Cro Bot Bot Bot Bot Bot Bot Bot Bot Bot Bo	ial Values - -Section Va n Internal F n Ratio tom flange tom flange tom flange tom flange tom flange tom flange tom flange mary torsion stic torsion: ear stress ir	Steel S 235   alues - IU 43 orces yield strength yield strength ulus of botton hal moment wi sional moment shear force in plastic shear al capacity of h bottom flang	DIN 1880 2/300/20/ in in shear in flange th respect ti t with respect in local y-din capacity in bottom flar bottom flar je	12/180/12/6/6 to web center act to web center action local y-direction ige			Fy.τ.fu           IT,fu           Tprim           Tsec           Vy,fu           Vpl,y,fu           Tprim,fu           Tpl,fu           Tpl,fu	12.60 9.93 0.00 458.59 3.25 272.09 0.00 157.81 0.15	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN kN kN				157.1	300		-
Mater Cross Cross Desig Desig Desig Bot Bot Cro Bot Bot Bot Bot Bot Bot Bot Bot Bot Bo	ial Values - -Section Va n Internal F n Ratio tom flange tom flange tom flange tom flange tom flange tom flange tom flange mary torsion stic torsion: ear stress ir	Steel S 235   alues - IU 43 orces yield strength yield strength ulus of botton hal moment wi sional moment shear force in plastic shear al capacity of h bottom flang	DIN 1880 2/300/20/ in in shear in flange th respect ti t with respect in local y-din capacity in bottom flar bottom flar je	12/180/12/6/6 to web center ect to web center ection local y-direction ige			fy,τ,fu           IT,fu           Tprim           Tsec           Vy,fu           Vpl,y,fu           Tprim,fu           Tpl,fu	12.60 9.93 0.00 458.59 3.25 272.09 0.00 157.81	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN kN kNcm kNcm	≤ 1.000			157.1	300		-
Mater Cross Cross Desig Desig Desig Bot Bot Cro Bot Bot Bot Bot Bot Bot Bot Bot Bot Bo	ial Values - -Section Va n Internal F n Ratio tom flange tom flange tom flange tom flange tom flange tom flange tom flange mary torsion stic torsion: ear stress ir	Steel S 235   alues - IU 43 orces yield strength yield strength ulus of botton hal moment wi sional moment shear force in plastic shear al capacity of h bottom flang	DIN 1880 2/300/20/ in in shear in flange th respect ti t with respect in local y-din capacity in bottom flar bottom flar je	12/180/12/6/6 to web center act to web center action local y-direction ige			Fy.τ.fu           IT,fu           Tprim           Tsec           Vy,fu           Vpl,y,fu           Tprim,fu           Tpl,fu           Tpl,fu	12.60 9.93 0.00 458.59 3.25 272.09 0.00 157.81 0.15	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN kN kNcm kNcm	≤ 1.000			157.1	300		-
Mater Cross Cross Desig Desig Desig Bot Bot Cro Bot Bot Bot Bot Bot Bot Bot Bot Bot Bo	ial Values - -Section Va n Internal F n Ratio tom flange tom flange tom flange tom flange tom flange tom flange tom flange mary torsion stic torsion: ear stress ir	Steel S 235   alues - IU 43 orces yield strength yield strength ulus of botton hal moment wi sional moment shear force in plastic shear al capacity of h bottom flang	DIN 1880 2/300/20/ in in shear in flange th respect ti t with respect in local y-din capacity in bottom flar bottom flar je	12/180/12/6/6 to web center act to web center action local y-direction ige			Fy.τ.fu           IT,fu           Tprim           Tsec           Vy,fu           Vpl,y,fu           Tprim,fu           Tpl,fu           Tpl,fu	12.60 9.93 0.00 458.59 3.25 272.09 0.00 157.81 0.15	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN kN kNcm kNcm	≤ 1.000			157.1	300		-
Mater Cross Cross Desig Desig Desig Bot Bot Cro Bot Bot Bot Bot Bot Bot Bot Bot Bot Bo	ial Values - -Section Va n Internal F n Ratio tom flange tom flange tom flange tom flange tom flange tom flange tom flange mary torsion stic torsion: ear stress ir	Steel S 235   alues - IU 43 orces yield strength yield strength ulus of botton hal moment wi sional moment shear force in plastic shear al capacity of h bottom flang	DIN 1880 2/300/20/ in in shear in flange th respect ti t with respect in local y-dim capacity in bottom flar bottom flar je	12/180/12/6/6 to web center act to web center action local y-direction ige			Fy.τ.fu           IT,fu           Tprim           Tsec           Vy,fu           Vpl,y,fu           Tprim,fu           Tpl,fu           Tpl,fu	12.60 9.93 0.00 458.59 3.25 272.09 0.00 157.81 0.15	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN kN kNcm kNcm	≤ 1.000			157.1	300		-
Mater Cross Cross Desig Desig Desig Bot Bot Cro Bot Bot Bot Bot Bot Bot Bot Bot Bot Bo	ial Values - -Section Va n Internal F n Ratio tom flange tom flange tom flange tom flange tom flange tom flange tom flange mary torsion stic torsion: ear stress ir	Steel S 235   alues - IU 43 orces yield strength yield strength ulus of botton hal moment wi sional moment shear force in plastic shear al capacity of h bottom flang	DIN 1880 2/300/20/ in in shear in flange th respect ti t with respect in local y-dim capacity in bottom flar bottom flar je	12/180/12/6/6 to web center act to web center action local y-direction ige			Fy.τ.fu           IT,fu           Tprim           Tsec           Vy,fu           Vpl,y,fu           Tprim,fu           Tpl,fu           Tpl,fu	12.60 9.93 0.00 458.59 3.25 272.09 0.00 157.81 0.15	kN/cm <sup>2</sup> cm <sup>4</sup> kNcm kNcm kN kN kNcm kNcm	≤ 1.000			157.1	300		-

Figure 8.11: Check of shear resistance in top flange

### Partial internal forces in cross-section parts according to [1], Table 10.17

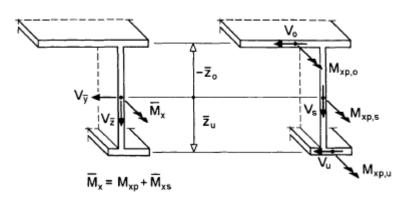


Figure 8.12: Partial internal forces  $\tau$  in cross-section consisting of three plates according to Figure 10.40 [1]

$$V_{U} = \frac{-(V_{\overline{y}} \cdot \overline{z}_{t} + \overline{M}_{xs})}{(\overline{z}_{b} - \overline{z}_{t})}$$
$$V_{U} = \frac{-(28.28 \cdot 0.21 + 4.589)}{((0.206 + 0.21))}$$
$$V_{U} = \underline{3.24 \text{ kN}}$$

4 Diubal

### Limiting plastic internal forces according to [1], Table 10.17

$$\begin{split} V_{pl,b} &= \tau_{Rd} \cdot b_{b} \cdot t_{b} \\ V_{pl,b} &= 12.60 \cdot 18.0 \cdot 1.2 \\ W_{pl,b} &= \underline{272.09 \, kN} \\ M_{pl,xp,b} &= \underline{\frac{\tau_{Rd} \cdot t_{b}^{2} \cdot (2 \cdot b_{b} - t_{b})}{4}} \\ M_{pl,xp,b} &= \frac{12.60 \cdot 1.2^{2} \cdot (2 \cdot 18.0 - 1.2)}{4} \\ M_{pl,xp,b} &= \underline{157.81 \, kNcm} \end{split}$$

$$\tau_{b} = \frac{\left|M_{xp,b}\right|}{2 \cdot M_{pl,xp,b}} + \sqrt{\left(\frac{M_{xp,b}}{2 \cdot M_{pl,xp,b}}\right)^{2} + \left(\frac{V_{t}}{V_{pl,b}}\right)^{2}} \cdot \frac{f_{y,d}}{\sqrt{3}}$$
  
$$\tau_{b} = \frac{\left|0.00\right|}{2 \cdot 157.81} + \sqrt{\left(\frac{0.00}{2 \cdot 157.81}\right)^{2} + \left(\frac{3.24}{272.09}\right)^{2}} \cdot \frac{f_{y,d}}{\sqrt{3}} = \underline{0.151 \text{ kN/cm}^{2}}$$
  
$$\Rightarrow \frac{\tau_{b}}{\tau_{Rd}} = \underline{0.012 \le 1.00}$$



# 8.2.5 Check of Allowable Bending Moment in Top Flange

	A	В	С	D	E						F		
	Member	Location	Load	Design									
No.	No.	x [m]	Case	Ratio			Design According to Formula						
1	IU 432/3	00/20/12/18	80/12/6/6										
	1	0.000	LC1				heck of shear flo		je				
	1	0.000	LC1				heck of shear flo						
	1	0.000	LC1				heck of shear flo						
	1	0.001	LC1				heck of the acc						
	1	0.001	LC1				5) Check of the acceptable bending moment in bottom flange 6) Check of the minimum acceptable nomal force acting on cross-section 7) Check of the maximum acceptable nomal force acting on cross-section						
	1	0.000	LC1										
	1	0.000	LC1										
	1	0.001	LC1								bout the major a		
	1	0.001	LC1	0.797	≤ 1	109) C	heck of the max	mum accepta	able bendin	ig moment a	about the major a	EXIS	
			Max:	0.797	≤1	۲					🗈 🛃 ≥	1,0 🔻	7 🗳 🛃 🍾
Pla:	flange be duced top f stic axial ca stic bendin	apacity of top g capacity of	trength (due flange ftop flange	al z-axis e to shear and tor about local z-axis ige bending capa			Mz, fo fy, τ, fo Npl, fo Mpl,z, fo Mz, fo/Mpl,z, fi	-5526.81 21.81 1308.37 9812.80 0.56	kN/cm <sup>2</sup> kN	≤ 1.000		432.0	

Figure 8.13: Check of the allowable bending moment at top flange

### Partial internal forces in cross-section parts according to [1], Table 10.20

### Limiting plastic internal forces according to [1], Table 10.20

 $M_{pl,t,\tau} = \frac{N_{pl,o,\tau} \cdot b_o}{4}$  $M_{pl,t,\tau} = \frac{1308.37 \cdot 30.0}{4}$  $M_{pl,t,\tau} = \frac{9813.65 \text{ kNcm} = 98.14 \text{ kNm}}{4}$ 

$$\frac{\left| M_{\text{Sa,t}} \right|}{M_{\text{pl,t,t}}} \le 1 + \delta_t^2 \implies \delta_t = 2 \cdot \overline{y_t} / b_t = \underline{0.0 \text{ cm}}$$
$$\frac{\left| -5528.50 \right|}{9813.65} = \underline{0.563} \le 1.00$$



# 8.2.6 Check of Allowable Bending Moment in Bottom Flange

	A	B	C	D	E						F				
Section	Member	Location	Load	Design											
No.	No.	x [m]	Case	Ratio							э.				
1	IU 432/3	00/20/12/18	0/12/6/6												
	1	0.000	LC1	0.033	≤1	101) Check	of shear flow	v in top flang	je						
	1	0.000	LC1				of shear flow								
	1	0.000	LC1				of shear flow								
	1	0.001	LC1				of the allowa								
	1	0.001	LC1				15) Check of the allowable bending moment in bottom flange 16) Check of the minimum acceptable normal force acting on cross-section								
	1	0.000	LC1												
	1	0.000	LC1								g on cross-sec				
	1	0.001	LC1								bout the major				
	1	0.001	LC1	0.797	≤1	109) Check	of the maxim	ium accepta	able bendin	g moment a	about the major	axis			
			Max:	0.797	≤1	۲					🗈 칠 🛛	> 1.0	•	7 😂 🛃 🔇	
∃ Mater ∃ Cross ∃ Desig	ial Values - -Section Va n Internal F		DIN 18800	):1990-11 12/180/12/6/6								1 - IL	J 432/3	300/20/1 2/1 80/1 2/6/6	
Ð Mater Ð Cross Ð Desig Ə Desig Top	ial Values - -Section Va n Internal F n Ratio p flange ber	Steel S 235 alues - IU 43 forces nding momen	I DIN 18800 2/300/20/	12/180/12/6/6 al z-axis		Mz,		-5526.81				1 - IL 	J 432/3	300.0	
E Mater E Cross Desig Desig Desig Re	ial Values - -Section Va n Internal F n Ratio p flange ber duced top f	Steel S 235 alues - IU 43 orces nding momen lange yield st	t about loca	12/180/12/6/6	sion ac	ction) fy. t	τ.fo	21.81	kN/cm <sup>2</sup>			1-IL	J 432/3		
Mater Cross Desig Desig Desig Re Pla	ial Values - -Section Va n Internal F n Ratio p flange ber duced top f stic axial ca	Steel S 235   alues - IU 43 orces nding momen lange yield st apacity of top	I DIN 18800 2/300/20/ t about loca trength (due flange	12/180/12/6/6 al z-axis to shear and tors	sion ac	ction) f <sub>y.t</sub> Npl	τ,fo l,fo	21.81 1308.37	kN/cm <sup>2</sup> kN			1-N	_	300.0	
Mater Cross Desig Desig Desig Re Pla Pla	ial Values - -Section Va n Internal F n Ratio p flange ber duced top f stic axial ca stic bending	Steel S 235 alues - IU 43 orces nding momen lange yield st apacity of top g capacity of	DIN 18800 (2/300/20/ tt about loca trength (due flange top flange	12/180/12/6/6 al z-axis to shear and tors about local z-axis		ction) f <sub>y, t</sub> N <sub>pl</sub> M <sub>pl</sub>	τ.fo l,fo l,z,fo	21.81	kN/cm <sup>2</sup> kN	≤ 1.000			1.7212	300.0	
Mater Cross Desig Desig Desig Re Pla Pla	ial Values - -Section Va n Internal F n Ratio p flange ber duced top f stic axial ca stic bending	Steel S 235 alues - IU 43 orces nding momen lange yield st apacity of top g capacity of	DIN 18800 (2/300/20/ tt about loca trength (due flange top flange	12/180/12/6/6 al z-axis to shear and tors		ction) f <sub>y, t</sub> N <sub>pl</sub> M <sub>pl</sub>	τ,fo l,fo	21.81 1308.37 9812.80	kN/cm <sup>2</sup> kN	≤ 1.000			_		
Mater Cross Desig Desig Desig Re Pla Pla	ial Values - -Section Va n Internal F n Ratio p flange ber duced top f stic axial ca stic bending	Steel S 235 alues - IU 43 orces nding momen lange yield st apacity of top g capacity of	DIN 18800 (2/300/20/ tt about loca trength (due flange top flange	12/180/12/6/6 al z-axis to shear and tors about local z-axis		ction) f <sub>y, t</sub> N <sub>pl</sub> M <sub>pl</sub>	τ.fo l,fo l,z,fo	21.81 1308.37 9812.80	kN/cm <sup>2</sup> kN	≤ 1.000		1 - IL	_	300.0	
Mater Cross Desig Desig Desig Re Pla Pla	ial Values - -Section Va n Internal F n Ratio p flange ber duced top f stic axial ca stic bending	Steel S 235 alues - IU 43 orces nding momen lange yield st apacity of top g capacity of	DIN 18800 (2/300/20/ tt about loca trength (due flange top flange	12/180/12/6/6 al z-axis to shear and tors about local z-axis		ction) f <sub>y, t</sub> N <sub>pl</sub> M <sub>pl</sub>	τ.fo l,fo l,z,fo	21.81 1308.37 9812.80	kN/cm <sup>2</sup> kN	≤ 1.000			_		•
Mater Cross Desig Desig Desig Re Pla Pla	ial Values - -Section Va n Internal F n Ratio p flange ber duced top f stic axial ca stic bending	Steel S 235 alues - IU 43 orces nding momen lange yield st apacity of top g capacity of	DIN 18800 (2/300/20/ tt about loca trength (due flange top flange	12/180/12/6/6 al z-axis to shear and tors about local z-axis		ction) f <sub>y, t</sub> N <sub>pl</sub> M <sub>pl</sub>	τ.fo l,fo l,z,fo	21.81 1308.37 9812.80	kN/cm <sup>2</sup> kN	≤ 1.000			_		
Mater Cross Desig Desig Desig Re Pla Pla	ial Values - -Section Va n Internal F n Ratio p flange ber duced top f stic axial ca stic bending	Steel S 235 alues - IU 43 orces nding momen lange yield st apacity of top g capacity of	DIN 18800 (2/300/20/ tt about loca trength (due flange top flange	12/180/12/6/6 al z-axis to shear and tors about local z-axis		ction) f <sub>y, t</sub> N <sub>pl</sub> M <sub>pl</sub>	τ.fo l,fo l,z,fo	21.81 1308.37 9812.80	kN/cm <sup>2</sup> kN	≤ 1.000			_		•
Mater Cross Desig Desig Desig Re Pla Pla	ial Values - -Section Va n Internal F n Ratio p flange ber duced top f stic axial ca stic bending	Steel S 235 alues - IU 43 orces nding momen lange yield st apacity of top g capacity of	DIN 18800 (2/300/20/ tt about loca trength (due flange top flange	12/180/12/6/6 al z-axis to shear and tors about local z-axis		ction) f <sub>y, t</sub> N <sub>pl</sub> M <sub>pl</sub>	τ.fo l,fo l,z,fo	21.81 1308.37 9812.80	kN/cm <sup>2</sup> kN	≤ 1.000			_		- •
Mater Cross Desig Desig Desig Re Pla Pla	ial Values - -Section Va n Internal F n Ratio p flange ber duced top f stic axial ca stic bending	Steel S 235 alues - IU 43 orces nding momen lange yield st apacity of top g capacity of	DIN 18800 (2/300/20/ tt about loca trength (due flange top flange	12/180/12/6/6 al z-axis to shear and tors about local z-axis		ction) f <sub>y, t</sub> N <sub>pl</sub> M <sub>pl</sub>	τ.fo l,fo l,z,fo	21.81 1308.37 9812.80	kN/cm <sup>2</sup> kN	≤ 1.000			_		
Mater Cross Desig Desig Desig Re Pla Pla	ial Values - -Section Va n Internal F n Ratio p flange ber duced top f stic axial ca stic bending	Steel S 235 alues - IU 43 orces nding momen lange yield st apacity of top g capacity of	DIN 18800 (2/300/20/ tt about loca trength (due flange top flange	12/180/12/6/6 al z-axis to shear and tors about local z-axis		ction) f <sub>y, t</sub> N <sub>pl</sub> M <sub>pl</sub>	τ.fo l,fo l,z,fo	21.81 1308.37 9812.80	kN/cm <sup>2</sup> kN	≤ 1.000			_		
Mater Cross Desig Desig Desig Re Pla Pla	ial Values - -Section Va n Internal F n Ratio p flange ber duced top f stic axial ca stic bending	Steel S 235 alues - IU 43 orces nding momen lange yield st apacity of top g capacity of	DIN 18800 (2/300/20/ tt about loca trength (due flange top flange	12/180/12/6/6 al z-axis to shear and tors about local z-axis		ction) f <sub>y, t</sub> N <sub>pl</sub> M <sub>pl</sub>	τ.fo l,fo l,z,fo	21.81 1308.37 9812.80	kN/cm <sup>2</sup> kN	≤ 1.000			_		•
Mater Cross Desig Desig Desig Re Pla Pla	ial Values - -Section Va n Internal F n Ratio p flange ber duced top f stic axial ca stic bending	Steel S 235 alues - IU 43 orces nding momen lange yield st apacity of top g capacity of	DIN 18800 (2/300/20/ tt about loca trength (due flange top flange	12/180/12/6/6 al z-axis to shear and tors about local z-axis		ction) f <sub>y, t</sub> N <sub>pl</sub> M <sub>pl</sub>	τ.fo l,fo l,z,fo	21.81 1308.37 9812.80	kN/cm <sup>2</sup> kN	≤ 1.000			_		

Figure 8.14: Check of allowable bending moment in bottom flange

### Partial internal forces in cross-section parts according to [1], Table 10.20

### Limiting plastic internal forces according to [1], Table 10.20

$$M_{pl,b,\tau} = \frac{N_{pl,b,\tau} \cdot b_{b}}{4}$$
$$M_{pl,b,\tau} = \frac{471.24 \cdot 18.0}{4}$$
$$M_{pl,b,\tau} = \frac{2120.58 \text{ kNcm} = 21.21 \text{ kNm}}{4}$$

$$\frac{\left| M_{\text{Sa,b}} \right|}{M_{\text{pl,b,t}}} \le 1 + \delta_{\text{b}}^{2} \implies \delta_{\text{b}} = 2 \cdot \overline{y_{\text{b}}} / b_{\text{b}} = \underline{0.0 \text{ cm}}$$
$$\frac{\left| -716.49 \right|}{2120.58} = \underline{0.338 \le 1.00}$$



# 8.2.7 Check of Allowable Bending Moment

No.         x [m]         C           1         IU 432/30/20/12/180/1           1         0.000           1         0.000           1         0.000           1         0.000           1         0.000           1         0.000           1         0.000           1         0.001           1         0.001           1         0.001           1         0.001           1         0.001           1         0.001           1         0.001           1         0.001           1         0.001           1         0.001           1         0.001           1         0.001           1         0.001           0         Cross-Section Properties - Steel S 235 [           2         Design Internal Froces         IU 432           2         Design padi force in cross-sect           Design bending moment in cross         Allowable axia force in web           Miniuma allowable axia force in web         Maximum allowable axia force in Maxia force	LC1 LC1 LC1 LC1 LC1 LC1 LC1 LC1 LC1 LC1	0.20 0.01 0.56 0.33 0.00 0.79 0.79 0.79 0.79	$1 \le 1$ $2 \le 1$ $3 \le 1$ $9 \le 1$ $0 \le 1$ $0 \le 1$ $8 \le 1$ $8 \le 1$ $8 \le 1$	102) Cl 103) Cl 104) Cl 105) Cl 105) Cl 106) Cl 107) Cl 108) Cl 109) Cl		ow in web ow in bottom f wable bending wable bending mum allowabl imum allowabl mum allowabl	e ange moment i moment i e axial forc le axial forc e bending	n top flange n bottom fla ee acting on ce acting or moment abo moment ab	nge cross-section n cross-section but the major axis out the major axis		•	V 🕅 🕄 🖏
1         14/32/300/20/12/18/71           1         14/32/300/20/12/18/71           1         14/32/300/20/12/18/71           1         1         0.000           1         0.000         1           1         0.000         1           1         0.000         1           1         0.001         1           1         0.001         1           1         0.001         1           1         0.001         1           1         0.001         1           1         0.001         1           2         Design fatio         1           Design Ratio         Design Fatio         14/32           Design Bending momert in cross-sect         Design Bowable axial force in web           Minimum allowable axial force in meb         Minimum allowable axial force in web           Minimum allowable axial force in meb         Minimum allowable axial force in Maximum allowable axial force in Maxi	(12/6/6 LC1 LC1 LC1 LC1 LC1 LC1 LC1 LC1	0.03 0.20 0.01 0.56 0.33 0.00 0.00 0.79 0.79 0.79 0.79	$1 \le 1$ $2 \le 1$ $3 \le 1$ $9 \le 1$ $0 \le 1$ $0 \le 1$ $8 \le 1$ $8 \le 1$ $8 \le 1$	102) Cl 103) Cl 104) Cl 105) Cl 105) Cl 106) Cl 107) Cl 108) Cl 109) Cl	neck of shear flu neck of shear flu neck of the allon neck of the allon neck of the mini neck of the mini neck of the mini	ow in web ow in bottom f wable bending wable bending mum allowabl imum allowabl mum allowabl	e ange moment i moment i e axial forc le axial forc e bending	n top flange n bottom fla ee acting on ce acting or moment abo moment ab	nge cross-section n cross-section out the major axi out the major axi	s 1,0	•	7 😂 🗟 🗞
1         0.000         1           1         0.000         1           1         0.000         1           1         0.001         1           1         0.001         1           1         0.001         1           1         0.001         1           1         0.001         1           1         0.001         1           1         0.001         1           2         Design Attenal Properties - Steel S 235           235             2         Design Ratio         1         4.33           2         Design Ratio         Design Ratio         1           Design Ratio         Design Ratio         1         4.33           Design Ratio         1         1         1           Mainum allowable axial force in web         Minimum allowable axial force in Maximum allowable axial force in Maxi	LC1 LC1 LC1 LC1 LC1 LC1 LC1 LC1 LC1 LC1	0.20 0.01 0.56 0.33 0.00 0.79 0.79 0.79 0.79	$1 \le 1$ $2 \le 1$ $3 \le 1$ $9 \le 1$ $0 \le 1$ $0 \le 1$ $8 \le 1$ $8 \le 1$ $8 \le 1$	102) Cl 103) Cl 104) Cl 105) Cl 105) Cl 106) Cl 107) Cl 108) Cl 109) Cl	neck of shear flu neck of shear flu neck of the allon neck of the allon neck of the mini neck of the mini neck of the mini	ow in web ow in bottom f wable bending wable bending mum allowabl imum allowabl mum allowabl	ange 1 moment i 1 moment i 1 axial forc 1 axial forc 1 bending	n bottom fla e acting on ce acting or moment abo moment abo	nge cross-section n cross-section out the major axis out the major axis	s 1,0	•	y 😫 🗟 🐒
1         0.000         I           1         0.001         I           1         0.000         I           1         0.000         I           1         0.001         I           1         0.001         I           Design Internal Forces         IU43:           Design Internal Forces         IU43:           Design Partia         Design axial force in cross-sect           Design Dending moment in cross         Allowable axial force in web           Minimum allowable axial force in Maxial force in Maxianum allowable axial force in Maxianum allowa	LC1 LC1 LC1 LC1 LC1 LC1 LC1 LC1 LC1 LC1	0.20 0.01 0.56 0.33 0.00 0.79 0.79 0.79 0.79	$1 \le 1$ $2 \le 1$ $3 \le 1$ $9 \le 1$ $0 \le 1$ $0 \le 1$ $8 \le 1$ $8 \le 1$ $8 \le 1$	102) Cl 103) Cl 104) Cl 105) Cl 105) Cl 106) Cl 107) Cl 108) Cl 109) Cl	neck of shear flu neck of shear flu neck of the allon neck of the allon neck of the mini neck of the mini neck of the mini	ow in web ow in bottom f wable bending wable bending mum allowabl imum allowabl mum allowabl	ange 1 moment i 1 moment i 1 axial forc 1 axial forc 1 bending	n bottom fla e acting on ce acting or moment abo moment abo	nge cross-section n cross-section out the major axis out the major axis	s 1,0	•	V 😂 🗟 🖏
1         0.000         I           1         0.001         I           1         0.001         I           1         0.000         I           1         0.000         I           1         0.000         I           1         0.001         I           1         0.001         I           1         0.001         I           2         Coss-Section Properties - Steel S 2351         Besign Ratio           Design Ratio         Design Ratio         Design Ratio           Design Ratio         Design Internal Forces         Id Asthered Force           Minimum allowable axial force in web         Minimum allowable axial force i         Minimum allowable axial force i           Maximum allowable axial force in Maximum allowable axial force i         Minimum allowable axial force i         Minimum allowable axial force i           Minimum allowable axial force i         Minimum allowable axial force i         Minimum allowable axial force i	LC1 LC1 LC1 LC1 LC1 LC1 LC1 LC1 LC1 LC1	0.01 0.56 0.33 0.00 0.00 0.79 0.79 0.79	$2 \le 1$ $3 \le 1$ $9 \le 1$ $0 \le 1$ $0 \le 1$ $8 \le 1$ $8 \le 1$ $8 \le 1$	103) Cl 104) Cl 105) Cl 106) Cl 106) Cl 107) Cl 108) Cl 109) Cl	heck of shearfle heck of the allon heck of the allon heck of the mini heck of the max heck of the mini	ow in bottom f wable bending wable bending mum allowabl imum allowabl mum allowabl	moment i moment i axial forc axial forc bending	n bottom fla e acting on ce acting or moment abo moment abo	nge cross-section n cross-section out the major axis out the major axis	s 1,0	•	9 <b>2 3</b>
1         0.001         I           1         0.001         I           1         0.000         I           1         0.000         I           1         0.001         I           1         0.001         I           1         0.001         I           1         0.001         I           2         Material Properties - Steel S 235         I           2         Design Itema Forces         Design Ratio           Design Ratio         Design Ratio         Design Ratio           Design Ratio         Design Itema Forces         IM 43:           Design Ratio         Design Ratio         Design Ratio           Maximum allowable axial force in web         Minimum allowable axial force in Maximum allowable axial force	LC1 LC1 LC1 LC1 LC1 LC1 LC1 LC1 LC1 LC1	0.56 0.33 0.00 0.79 0.79 0.79 0.79	$3 \le 1$ $9 \le 1$ $0 \le 1$ $0 \le 1$ $8 \le 1$ $8 \le 1$ $8 \le 1$	104) Ci 105) Ci 106) Ci 107) Ci 108) Ci 108) Ci	heck of the allo heck of the allo heck of the mini heck of the max heck of the mini	vable bending wable bending mum allowabl imum allowab mum allowabl	moment i moment i axial forc axial forc bending	n bottom fla e acting on ce acting or moment abo moment abo	nge cross-section n cross-section out the major axis out the major axis	s 1,0	•	V 😂 🖼 🕅
1         0.001         I           1         0.000         I           1         0.000         I           1         0.001         I           1         0.001         I           1         0.001         I           1         0.001         I           Details - Member 1 - x: 0.001 m - LC         Image: Construction Properties - Steel S 2351           Design Internal Forces         IU 432           Design Partice         Design axial force in cross-sect           Design bending moment in cross         Allowable axial force in web           Minimum allowable axial force in         Minimum allowable axial force in           Maximum allowable axial force in         Minimum allowable axial force in           Minimum allowable axial force in         Minimum allowable axial force in           Maximum allowable axial force in         Minimum allowable axial force in	LC1 LC1 LC1 LC1 LC1 LC1 LC1 LC1 LC1 LC1	0.33 0.00 0.00 0.79 0.79 0.79	9 ≤1 0 ≤1 8 ≤1 8 ≤1 8 ≤1	105) CH 106) CH 107) CH 108) CH 109) CH	heck of the allon heck of the mini heck of the max heck of the mini	wable bending mum allowabl imum allowab mum allowabl	nomenti axial forc axial for bending	n bottom fla e acting on ce acting or moment abo moment abo	nge cross-section n cross-section out the major axis out the major axis	s 1,0	•	9 <b>2 3</b>
1         0.000         I           1         0.001         I           1         0.001         I           1         0.001         I           1         0.001         I           Details - Member 1 - x: 0.001 m - LC         Material Properties - Steel S 2351           2 Cross-Section Properties - VEel S 2351         Design Ratio           Design Ratio         Design Ratio           Design Ratio         Devalation force in cross-act           Mirriumu allowable axial force i         Maimum allowable axial force in           Mirriumu allowable axial force in         Maimum allowable axial force in           Mirriumu allowable axial force in         Maimum allowable axial force in           Mirriumu allowable axial force in         Maimum allowable axial force in           Mirriumu allowable axial force in         Maimum allowable axial force in           Maimum allowable axial force in         Maimum allowable axial force in	LC1 LC1 LC1 LC1 LC1 C1 .C1 .C1 .DIN 18	0.00 0.79 0.79 0.79 0.79	D ≤1 D ≤1 8 ≤1 8 ≤1 8 ≤1	106) CH 107) CH 108) CH 109) CH	heck of the mini heck of the max heck of the mini	- mum allowabl imum allowabl mum allowabl	e axial forc le axial forc e bending	e acting on ce acting or moment abo moment ab	cross-section n cross-section out the major axis out the major axis	s 1,0	•	9 <b>2 3</b>
1         0.000         I           1         0.001         I           1         0.001         I           1         0.001         I           2         I         0.001         I           1         0.001         I         I           2         I         0.001         I           2         Design Partice         Steel S 235         I           2         Design Internal Forces         Design Partice         Design Partice           Design paraial force in cross-sect         Design axial force in web         Minimum allowable axial force i           Minimum allowable axial force in Maximum allowable axial force in         Minimum allowable axial force in         Minimum allowable axial force in           Maximum allowable axial force in         Minimum allowable axial force in         Minimum allowable axial force in           Minimum allowable axial force in         Minimum allowable axial force in         Minimum allowable axial force in	LC1 LC1 LC1 Max:	0.00 0.79 0.79 0.79 0.79	D ≤1 8 ≤1 8 ≤1 8 ≤1	107) Cr 108) Cr 109) Cr	heck of the max heck of the mini	imum allowab mum allowabl	le axial for e bending	ce acting or moment abo moment ab	n cross-section out the major axis out the major ax	s 1,0	•	7 😂 🛋 🖏
1         0.001         L           1         0.001         L           Internal Froperties - Sciel S 2351         Conso-Section Properties - Sciel S 2351           2 Design Internal Forces         Design Partice         Design Partice           Design Partice         Design Partice         Design Partice           Martinet and Broces         Martinet Partice         Martinet Partice           Minimum allowable axial force in web         Minimum allowable axial force in Martinum allowable axial f	LC1 LC1 Max:	0.79 0.79 0.79 800:1990-11	8 ≤ 1 8 ≤ 1 8 ≤ 1	108) Ci 109) Ci	heck of the mini	mum allowabl	e bending	moment abo moment ab	out the major axis out the major ax	s 1,0	•	y 😂 🛃 👔
1 0.001 L      Details - Member 1 - x: 0.001 m - LC      Datarial Properties - Steel S 235 [         Cross-Section Properties - 1U 43:         Design Internal Forces         Design Ratio     Design Ratio     Design Internal Forces     Design Internal Forces     Design Internal Forces     Design Internal Forces     Design Internal Powable axial force in     Maximum allowable axial force i     Minimum allowable axial force i	LC1 Max:	0.79	8 <u>≤</u> 1 8 ≤1	109) Cł				moment ab	out the major ax	s 1,0	•	y 😂 🛃 🕅
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										a		

Figure 8.15: Check of allowable bending moment about major axis

### Limiting axial forces in flanges according to [1], Table 10.18

$$\begin{split} \frac{M_{Sa,t}}{M_{pl,t,\tau}} &= 0.563 \ge 2 \cdot \delta_t = 0.0 \\ N_{lim,t,min} &= N_{pl,t,\tau} \cdot \left( -\delta_t - \sqrt{\delta_t^2 + 1 - \left(\frac{M_{Sa,t}}{M_{pl,t,\tau}}\right)} \right) \\ N_{lim,t,min} &= 1308.87 \cdot \left( -0.0 - \sqrt{0.0^2 + 1 - 0.563} \right) \\ N_{lim,t,min} &= -\frac{864.52 \text{ kN}}{M_{pl,b,\tau}} \Longrightarrow N_{lim,t,max} = \frac{864.52 \text{ kN}}{M_{pl,b,\tau}} \\ \frac{M_{Sa,b}}{M_{pl,b,\tau}} &= 0.339 \ge 2 \cdot \delta_t = 0.0 \\ N_{lim,b,min} &= N_{pl,b,\tau} \cdot \left( -\delta_b - \sqrt{\delta_b^2 + 1 - \left(\frac{M_{Sa,b}}{M_{pl,b,\tau}}\right)} \right) \\ N_{lim,b,min} &= 471.24 \cdot \left( -0.0 - \sqrt{0.0^2 + 1 - 0.339} \right) \\ N_{lim,b,min} &= -\frac{383.45 \text{ kN}}{M_{pl,b,max}} \Longrightarrow N_{lim,b,max} = \frac{383.45 \text{ kN}}{M_{pl,b,max}} \end{split}$$

Limiting axial force according to [1], Table 10.20

$$\begin{split} N_{lim,w,max} &= h_w \cdot t_w \cdot f_{y,d} \cdot \sqrt{1 - \left(\frac{\tau_w}{\tau_{Rd}}\right)^2} \\ N_{lim,w,max} &= 40.0 \cdot 1.2 \cdot 21.82 \cdot \sqrt{1 - 0.201^2} \\ N_{lim,w,max} &= 1025.85 \text{ kN} \end{split}$$



#### Governing case according to [1], Table 10.19

Because N = 0, all possible cases for determining max  $M_y$  are met. Therefore, the limiting bending moments are determined for all three cases. The minimum value is governing.

• Case 1:  $\min M_{\overline{y}} = N_{\lim,b,\min} \cdot (\overline{z_b} - \overline{z_t}) + (N + N_{\lim,w}) \cdot \overline{z_t}$   $\min M_{\overline{y}} = -383.45 \cdot (0.206 - (-0.21)) + (0.00 + 1025.85) \cdot (-0.21)$   $\min M_{\overline{y}} = -374.94 \text{ kNm}$ 

• Case 2:

$$\begin{split} & \mathsf{N}_{\mathsf{w}} = \mathsf{N} - \mathsf{N}_{\mathsf{lim},\mathsf{t},\mathsf{max}} - \mathsf{N}_{\mathsf{lim},\mathsf{b},\mathsf{min}} \\ & \mathsf{N}_{\mathsf{w}} = 0.00 - 864.52 - (-383.45) \\ & \mathsf{N}_{\mathsf{w}} = \underline{-481.07 \,\mathsf{kN}} \\ & \mathsf{minM}_{\overline{\mathsf{y}}} = \mathsf{N}_{\mathsf{lim},\mathsf{b},\mathsf{min}} \cdot \overline{\mathsf{z}_{\mathsf{b}}} + \mathsf{N}_{\mathsf{lim},\mathsf{t},\mathsf{max}} \cdot \overline{\mathsf{z}_{\mathsf{t}}} - \frac{\left(\mathsf{N}^{2}_{\mathsf{lim},\mathsf{w}} - \mathsf{N}^{2}_{,\mathsf{w}}\right) \cdot \mathsf{h}_{\mathsf{w}}}{\left(4 \cdot \mathsf{N}_{\mathsf{lim},\mathsf{w}}\right)} \\ & \mathsf{minM}_{\overline{\mathsf{y}}} = -383.45 \cdot 0.206 + 864.52 \cdot (-0.21) - \frac{\left(1025.85^{2} - 481.07^{2}\right) \cdot 0.40}{\left(4 \cdot 1025.85\right)} \\ & \mathsf{minM}_{\overline{\mathsf{y}}} = \underline{-340.57 \,\mathsf{kNm}} \quad \Rightarrow \quad \mathsf{governing} \end{split}$$

• Case 3:

$$\begin{split} \min M_{\overline{y}} &= -N_{\lim,t,max} \cdot \left(\overline{z_{b}} - \overline{z_{t}}\right) + \left(N - N_{\lim,w}\right) \cdot \overline{z}_{b} \\ \min M_{\overline{y}} &= -864.52 \cdot \left(0.206 - (-0.21)\right) + \left(0.00 - 1025.85\right) \cdot (0.206) \\ \min M_{\overline{y}} &= -570.97 \text{ kNm} \end{split}$$

Check according to [1], Table 10.19

 $\frac{M_{y}}{\min M_{y}} \le 1.00$  $\frac{27,159.00}{34,057.00} = \underbrace{0.797 \le 1.00}_{= 1.00}$ 



# 8.3 Circular Hollow Section

The following example is presented in [1], page 446.

### **Cross-section**

Cross-section pipe 273/8

Steel S 235

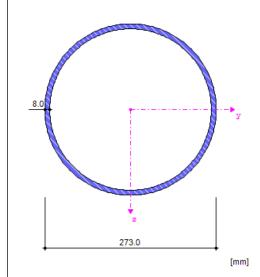


Figure 8.16: Cross-section pipe 273/8

### **Cross-section properties**

Cross-section property	Symbol	Value	Unit
Outer diameter	D	273.000	mm
Wall thickness	s	8.000	mm
Cross-sectional area	A	66.600	cm <sup>2</sup>
Shear area	Ay	33.040	cm <sup>2</sup>
Core area	A <sub>c</sub>	551.550	cm <sup>2</sup>
Moment of inertia	l <sub>y</sub>	5851.710	cm <sup>4</sup>
Polar moment of inertia	I <sub>p</sub>	8275.570	cm⁴
Governing radius of gyration	r <sub>y</sub>	93.700	mm
Polar radius of gyration	r <sub>o</sub>	132.600	mm
Weight	wt	52.300	kg/m
Surface	A <sub>surf</sub>	0.858	m²/m
Torsional constant	L	11,692.800	cm <sup>4</sup>
Section modulus for torsion	St	856.610	cm <sup>3</sup>
Elastic section modulus	Sy	428.700	cm <sup>3</sup>
Statical moment of area	Q <sub>y,max</sub>	140.490	cm <sup>3</sup>
Plastic section modulus	Z <sub>y,max</sub>	561.970	cm <sup>3</sup>

Table 8.3: Cross-section properties for pipe 273/8

### Loading

Shear force	$V_{\text{Ed}}$	=	116.00 kN
Moment	M <sub>T,Ed</sub>	=	40.00 kNm
Moment	$M_{\text{y,Ed}}$	=	100.00 kNm

## 8.3.1 Check of Shear Resistance

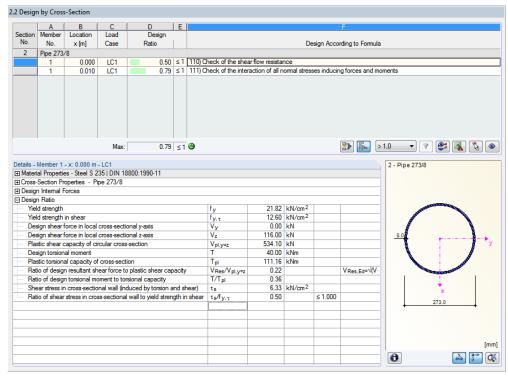


Figure 8.17: Check of shear resistance

### **Material properties**

$$f_{y,d} = \frac{f_{y,k}}{\gamma_{M}} = \frac{24.00}{1.1} = \underbrace{\frac{21.82 \text{ kN/cm}^{2}}{\sqrt{3}}}_{\tau_{Rd}} = \underbrace{\frac{f_{y,d}}{\sqrt{3}}}_{\sqrt{3}} = \underbrace{\frac{21.82}{\sqrt{3}}}_{\frac{12.60 \text{ kN/cm}^{2}}{\sqrt{3}}}$$

Limiting plastic internal forces according to [1], Table 10.10

$$V_{pl,y,z} = 2 \cdot \frac{f_{y,d}}{\sqrt{3}} \cdot t \cdot (d-t)$$

$$V_{pl,y,z} = 2 \cdot \frac{21.82}{\sqrt{3}} \cdot 0.8 \cdot (27.30 - 0.8)$$

$$V_{pl,y,z} = \underline{534.10 \text{ kN}}$$

$$M_{pl,x} = \pi \cdot \frac{f_{y,d}}{\sqrt{3}} \cdot t \cdot (d-t)^2 / 2$$

$$M_{pl,x} = \pi \cdot \frac{f_{y,d}}{\sqrt{3}} \cdot 0.8 \cdot (27.30 - 0.8)^2 / 2$$

$$M_{pl,x} = 11,116.28 \text{ kNcm} = \underline{111.16 \text{ kNm}}$$



### Check according to [1], Table 10.10

The check conditions given in Table 10.10 apply to the linear interaction. In RF-STEEL Plastic, however, the iterative method of the exact solution is implemented. Thus, you obtain higher resistances for this example than given in [1].

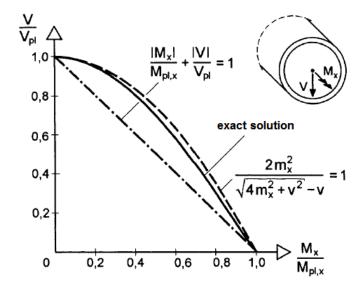


Figure 8.18:  $M_x$ -V interaction (exact solution and approximations)

#### Linear interaction

$$\tau = \frac{|V|}{V_{pl}} + \frac{|M_x|}{M_{pl,x}} \cdot \frac{f_{y,d}}{\sqrt{3}}$$
  
$$\tau = \frac{|116|}{534.10} + \frac{|40|}{116.16} \cdot \frac{f_{y,d}}{\sqrt{3}} = 7.25 \text{ kN/cm}^2$$
  
$$\Rightarrow \frac{\tau}{\tau_{Rd}} = \underbrace{0.57 \le 1.00}_{Rd}$$

#### **Exact solution**

$$\tau = 6.33 \,\text{kN/cm}^2 \implies \frac{\tau}{\tau_{\text{Rd}}} = \underbrace{0.50 \le 1.00}_{\text{mag}}$$



#### 2.2 Design by Cross-Section A B C Section Member Location Load No. x [m] Case C Load D Design E Ratio Design According to Formula 2 Pipe 273/8 0.50 ≤ 1 110) Check of the shear flow resistance 0.79 ≤ 1 111) Check of the interaction of all normal stresses inducing forces and mome 0.000 LC1 0.010 LC1 1 Max: 0.79 ≤1 🥹 🗈 🔄 >1.0 🔷 🍼 🕰 🖏 💿 Details - Member 1 - x: 0.010 m - LC1 ☑ Material Properties - Steel S 235 | DIN 18800:1990-11 ☑ Cross-Section Properties - Pipe 273/8 2 - Pipe 273/8 El Cross-Section Properties - Pipe Design Internal Forces Design Ratio Yield strength Yield strength in shear Yield strength reduction factor 21.82 kN/cm<sup>2</sup> f<sub>y.τ</sub> 12.60 kN/cm<sup>2</sup> 0.86 $\begin{array}{c} \mbox{Field strength reduction factor} \\ \mbox{Yield strength reduced due to shear and torsion action} \\ \mbox{Design axial force} \\ \mbox{Plastic axial capacity of cross-section (reduced due to torsion and sh} \\ \mbox{Np}_{1\tau} \\ \mbox{Total force to reduced plastic axial capacity} \\ \mbox{NVP}_{1\tau} \\ \mbox{Total force to reduced plastic axial capacity} \\ \mbox{VVP}_{1\tau} \\ \mbox{Total force to reduced plastic axial capacity} \\ \mbox{VVP}_{1\tau} \\ \mbox{Total force to reduced plastic axial capacity} \\ \mbox{VVP}_{1\tau} \\ \mbox{Total force to reduced plastic axial capacity} \\ \mbox{VVP}_{1\tau} \\ \mbox{Total force to reduced plastic axial capacity} \\ \mbox{VVP}_{1\tau} \\ \mbox{Total force to reduced plastic axial capacity} \\ \mbox{Total force to reduced plastic axial capacit$ 18.86 kN/cm<sup>2</sup> 0.00 kN 1256.09 kN Ratio of design axial force to reduced plastic axial capacity Design bending moment about major axis Design bending moment about minor axis 0.00 100.00 kNm 0.00 kNm My Mz Design benuing interiment about minor axis $\begin{array}{l} \text{Mg}_{1}\\ \text{Plastic bending capacity of cross-section (reduced due to torsion and Mg)}_{1}\\ \text{Ratio of design bending moment about major axis to reduced plastic:} \\ \text{Mg}_{2}/Mg)_{\tau}\\ \text{Ratio of design bending moment bout minor axis to reduced plastic:} \\ \text{Ratio of design resultant bending moment to reduced plastic bending}\\ \text{Plastic interaction state} \\ \end{array}$ 105.95 kNm 0.94 0.94 M<sub>Res,Ed</sub>=√(M 0.79 ≤ 1.000 [mm] 0 🎽 🚰 🏹

### 8.3.2 Interaction of Normal and Bending Stresses

Figure 8.19: Interaction check of normal and bending stresses

#### **Reduction factor of yield strength**

$$\chi_{y} = \sqrt{1 - \left(\frac{\tau}{\tau_{R}}\right)^{2}} = \sqrt{1 - 0.504^{2}} = \underline{0.864}$$
  
redf<sub>y</sub> = f<sub>y</sub> ·  $\chi_{y}$  = 21.82 · 0.864 = 18.86 kN/cm<sup>2</sup>

### Limiting plastic internal forces according to [1], Table 10.10

$$\begin{split} N_{pl,\tau} &= \pi \cdot t \cdot (d-t) \cdot redf_y \\ N_{pl,\tau} &= \pi \cdot 0.8 \cdot (27.30 - 0.8) \cdot 18.86 \\ N_{pl,\tau} &= 1256.09 \, kN \end{split}$$

$$\begin{split} M_{pl,\tau} &= t \cdot (d-t)^2 \cdot redf_y \\ M_{pl,\tau} &= 0.8 \cdot (27.30 - 0.8)^2 \cdot 18.86 \\ M_{pl,\tau} &= 10595.55 \, kNcm = 105.96 \, kNm \end{split}$$

$$\frac{N}{N_{pl,\tau}} + \frac{2}{\pi} \cdot \arcsin\left(\frac{|M|}{M_{pl,\tau}}\right) \le 1.00$$
$$\frac{0.00}{1256.09} + \frac{2}{\pi} \cdot \arcsin\left(\frac{|100|}{105.96}\right) \le 1.00$$
$$\frac{0.79 \le 1.00}{100}$$



# 8.4 Rectangular Hollow Section

The following example is presented in [1], page 458.

### **Cross-section**

Rectangular hollow section TO 300/200/8

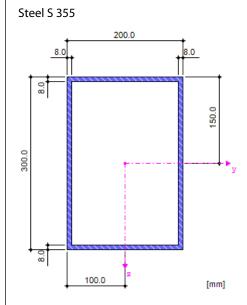


Figure 8.20: Rectangular hollow section TO 300/200/8

### **Cross-section properties**

Cross-section property	Symbol	Value	Unit
Depth	а	300.000	mm
Width	b	200.000	mm
Left wall thickness	t <sub>al</sub>	8.000	mm
Right wall thickness	t <sub>ar</sub>	8.000	mm
Upper wall thickness	t <sub>bt</sub>	8.000	mm
Lower wall thickness	t <sub>bb</sub>	8.000	mm
Cross-sectional area	A	77.440	cm <sup>2</sup>
Shear area	Ay	22.840	cm <sup>2</sup>
Shear area	Az	41.800	cm <sup>2</sup>
Core area	A <sub>c</sub>	560.640	cm <sup>2</sup>
Moment of inertia	ly	9877.000	cm <sup>4</sup>
Moment of inertia	lz	5256.840	cm <sup>4</sup>
Polar moment of inertia	I <sub>p</sub>	15,133.800	cm <sup>4</sup>
Governing radius of gyration	r <sub>y</sub>	112.900	mm
Governing radius of gyration	r <sub>z</sub>	82.400	mm
Polar radius of gyration	r <sub>o</sub>	139.800	mm
Weight	wt	60.800	kg/m
Surface	A <sub>surface</sub>	1.000	m²/m
Torsional constant	J	10,407.200	cm <sup>4</sup>
Warping constant referring to M	C <sub>w</sub>	21,647.200	cm <sup>6</sup>



Elastic section modulus	Sy	658.470	cm <sup>3</sup>
Elastic section modulus	Sz	525.680	cm <sup>3</sup>
Warping section modulus	Ww	747.520	cm⁴
Statical moment of area	Q <sub>y,max</sub>	197.460	cm <sup>3</sup>
Statical moment of area	Q <sub>z,max</sub>	149.060	cm <sup>3</sup>
Normalized warping constant	W <sub>no</sub>	28.960	cm <sup>2</sup>
Warping statical moment	Q <sub>w,max</sub>	149.810	cm⁴
Plastic section modulus	Z <sub>y,max</sub>	789.820	cm <sup>3</sup>
Plastic section modulus	Z <sub>z,max</sub>	596.220	cm <sup>3</sup>
Plastic shape factor	Z <sub>y,max/S_y</sub>	1.199	
Plastic shape factor	Z <sub>z,max/S_z</sub>	1.134	

Table 8.4: Cross-section properties TO 300/200/8

#### Loading

Shear force	$V_{\text{Ed}}$	=	48.00 kN
Moment	M <sub>T,Ed</sub>	=	24.00 kNm
Moment	$M_{\text{y,Ed}}$	=	240.00 kNm

## 8.4.1 Shear Resistance in Flanges

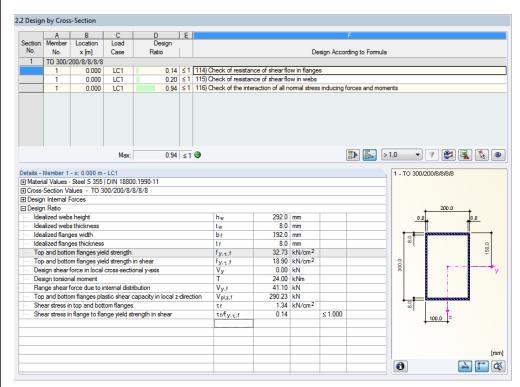


Figure 8.21: Check of shear resistance in flanges

#### **Material properties**

$$f_{y,d} = \frac{f_{y,k}}{\gamma_{M}} = \frac{36.00}{1.1} = \underbrace{\frac{32.73 \text{ kN/cm}^{2}}{\sqrt{3}}}_{\tau_{Rd}} = \underbrace{\frac{f_{y,d}}{\sqrt{3}}}_{\sqrt{3}} = \underbrace{\frac{32.73 \text{ kN/cm}^{2}}{\sqrt{3}}}_{=} \underbrace{\frac{18.90 \text{ kN/cm$$

. Dlubal

Limiting plastic internal forces according to [1], Table 10.14

$$\begin{split} V_{pl,flange} &= 2 \cdot b \cdot t_{G} \cdot \frac{f_{y,d}}{\sqrt{3}} & V_{pl,web} = 2 \cdot h_{w} \cdot t_{w} \cdot \frac{f_{y,d}}{\sqrt{3}} \\ V_{pl,flange} &= 2 \cdot 19.20 \cdot 0.80 \cdot \frac{32.73}{\sqrt{3}} & V_{pl,web} = 2 \cdot 29.20 \cdot 0.80 \cdot \frac{32.73}{\sqrt{3}} \\ V_{pl,flange} &= \frac{580.46 \, kN}{\sqrt{3}} & V_{pl,web} = \frac{883.00 \, kN}{\sqrt{3}} \end{split}$$

### Partial internal forces in cross-section parts

$$\begin{split} V_{flange} &= \frac{\left| V_{y} \right|}{2} + \frac{\left| M_{x} \right| \cdot b}{2 \cdot a_{g} \cdot a_{s}} \\ V_{glange} &= \frac{\left| 0.00 \right|}{2} + \frac{\left| 24 \right| \cdot 0.192}{2 \cdot 0.292 \cdot 0.192} \\ V_{flange} &= \frac{41.10 \text{ kN}}{2} \\ \end{split}$$





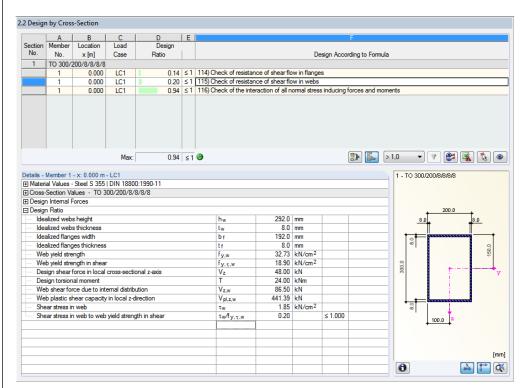


Figure 8.22: Check of shear resistance in web

$$\tau_{w} = \left(V_{z} + \frac{M_{x} \cdot h_{w}}{a_{f} \cdot a_{w}}\right) \cdot \frac{1}{V_{p,z}} \cdot \frac{f_{y,d}}{\sqrt{3}}$$
  
$$\tau_{w} = \left(48.00 + \frac{24.00 \cdot 0.292}{0.292 \cdot 0.192}\right) \cdot \frac{1}{883.00} \cdot 18.90 = 3.70 \text{ kN/ cm}^{2}$$
  
$$\Rightarrow \frac{\tau_{w}}{\tau_{Rd}} = \underbrace{0.20 \le 1.00}_{=}$$



	A	B	С	D	E				F				
	Member	Location	Load	Design									
No.	No.	x [m]	Case	Ratio				Desi	gn According to For	mula			
1	TO 300/2	200/8/8/8/8											
	1	0.000	LC1			114) Check of resis							
	1	0.000	LC1			115) Check of resis							
	1	0.000	LC1	0.94	≤1[	116) Check of the i	interaction of	all normal stress ir	nducing forces and	mome	ents		
			Max:	0.94	≤1	9			<b>P</b>	>	1,0	• • (	🞽 属 🐔
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	-Section Va n Internal F n Ratio	alues - TO 3 Forces								*		<u>↓ 20</u>	0.0
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	-Section Va n Internal F n Ratio alized web alized web	alues - TO 3 Forces s height s thickness				tw	8.0	mm				+	
E Cross E Desig E Desig Ide Ide Ide	-Section Va n Internal F n Ratio alized web alized web alized flang	alues - TO 3 Forces s height s thickness ges width	00/200/8/			t <sub>w</sub> bf	8.0 192.0	mm			19	+	8.0
E Cross Desig Desig Ide Ide Ide	Section Va n Internal F n Ratio alized web alized web alized flang alized flang	alues - TO 3 Forces s height s thickness ges width ges thickness	00/200/8/			t <sub>w</sub> br tr	8.0 192.0 8.0	mm mm			8.0	+	8.0
Cross Cross Consigned Con	Section Va n Internal F n Ratio alized web alized web alized flang alized flang o and botto	alues - TO 3 Forces s height s thickness ges width ges thickness om flanges yie	ld strength	8/8/8		tw bf tf fy.τ.f	8.0 192.0 8.0 32.73	mm mm kN/cm <sup>2</sup>				+	
Cross Cross Consigned Con	Section Va n Internal F n Ratio alized web alized web alized flang alized flang o and botto o and botto	alues - TO 3 Forces s height s thickness ges width ges thickness om flanges yie om flanges yie	ld strength	8/8/8 in shear		t <sub>w</sub> bf tf fy.τ.f fy.τ.f	8.0 192.0 8.0 32.73 18.90	mm mm kN/cm <sup>2</sup> kN/cm <sup>2</sup>				+	8.0
Tross     Cross     Desig     Desig     Ide     Ide     Ide     Ide     Ide     Top     Top     Rar	Section Va n Internal F n Ratio alized web alized web alized web alized flang alized flang and botto and botto and botto nges yield s	alues - TO 3 Forces s height s thickness ges width ges thickness om flanges yie om flanges yie strength reduc	ld strength	8/8/8	action	t <sub>w</sub> bf tf fy.τ.f fy.τ.f fy.τ.f	8.0 192.0 8.0 32.73 18.90 32.40	mm mm kN/cm <sup>2</sup> kN/cm <sup>2</sup> kN/cm <sup>2</sup>			300.0	+	8.0
Cross     Cross     Cross     Cross     Cross     Cross     Ide     Ide     Ide     Ide     Ide     Top     Top     Rar     We	Section Va n Internal F n Ratio alized web alized web alized web alized flang alized flang and botto and botto and botto b and botto b syleld stree	alues - TO 3 Forces s height s thickness ges width ges thickness om flanges yie om flanges yie strength reducength	ld strength Id strength Id strength	8/8/8 in shear	action	t <sub>w</sub> bf tf fy,τ,f fy,τ,f fy,τ,f fy,τ,red,f fy,w	8.0 192.0 8.0 32.73 18.90 32.40 32.73	mm mm kN/cm <sup>2</sup> kN/cm <sup>2</sup> kN/cm <sup>2</sup> kN/cm <sup>2</sup>				+	8.0
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Cross     Desig     Ide     Ide     Ide     Ide     Ide     Ide     Vor     Rar     We     We     We     Des     Des     Des     Des     Des     Des     Des     Des     Des     Pla     Pla	Section Va n Internal F n Ratio alized web alized web alized flang alized flang alized flang o and botto o and botto o and botto so and botto so and botto so and botto so and botto so and botto so and botto sign solal flang sign solal stra sign bendir sign b	alues - TO 3 Forces s height s thickness ges width ges thickness mm flanges yie strength reduce once g moment ab apacity of wei g capacity of wei g capacity of se	ld strength id strength ced due to sh wout major a sout minor a b (reduced web (reduced reduced	in shear shear and torsion hear and torsion a pois due to torsion an	ction d shear and sh and shear	tw bf tf fy, \tau, f fy, \tau, r fy, r, red, f fy, r, red, f f, r, red, f f, r,	8.0 192.0 8.0 32.73 18.90 32.40 32.73 18.90 32.09 0.00 240.00 0.240.00 0.00 749.69	mm         mm           mm         kN/cm²           kN/cm²         kN/cm²           kN/cm²         kN/cm²           kN/cm²         kN/cm²           kN/cm²         kN/cm²           kN/cm²         kN/cm²           kN/cm²         kN/cm²           kNm         kNm           kNm         kNm           kN         kN			300.0	8.0	8.0

### 8.4.3 Interaction of Normal and Bending Stresses

Figure 8.23: Interaction check of normal and bending stresses

Reduction factors of yield strength according to [1], Table 10.15

 $\operatorname{red} f_{y,f} = f_{y,f} \cdot \sqrt{1 - \left(\frac{\tau_{f}}{\tau_{Rd}}\right)^{2}} = 32.73 \cdot \sqrt{1 - 0.14^{2}} = \underline{32.40 \text{ kN/cm}^{2}}$  $\operatorname{red} f_{y,w} = f_{y,w} \cdot \sqrt{1 - \left(\frac{\tau_{w}}{\tau_{Rd}}\right)^{2}} = 32.73 \cdot \sqrt{1 - 0.20^{2}} = \underline{32.09 \text{ kN/cm}^{2}}$ 

### Limiting plastic internal forces according to [1], Table 10.15

$$\begin{split} N_{pl,f} = & redf_{y} \cdot b \cdot t_{f} \\ N_{pl,f} = & 32.40 \cdot 19.2 \cdot 0.8 \\ N_{pl,f} = & \underline{497.66 \ kN} \end{split} \qquad \begin{array}{l} N_{pl,w} = & redf_{y} \cdot h_{w} \cdot t_{w} \\ N_{pl,w} = & 32.09 \cdot 29.2 \cdot 0.8 \\ N_{pl,w} = & \underline{749.62 \ kN} \\ \end{array}$$

Check according to [1], Table 10.15 – case 1a

$$M_{pl,y} = N_{pl,f} \cdot a_{f} + \frac{h_{w}}{2 \cdot N_{pl,w}} \cdot \left[ N_{pl,w}^{2} - \frac{N^{2}}{4} - \left(\frac{M_{z}}{a_{f}}\right)^{2} \right]$$
$$M_{pl,y} = 497.66 \cdot 0.292 + \frac{0.292}{2 \cdot 749.62} \cdot \left[ 749.62^{2} - \frac{0^{2}}{4} - \left(\frac{0}{0.192}\right)^{2} \right]$$
$$M_{pl,y} = 254.76 \text{ kNm} \ge 240.00 \text{ kNm}$$

Design ratio : 
$$0.94 \le 1.00$$



# **A** Literature

- [1] Rolf KINDMANN, Jörg FRICKEL: Elastische und plastische Querschnittstragfähigkeit Grundlagen, Methoden, Berechnungsverfahren, Ernst & Sohn, Berlin, 2002
- [2] Plastic interaction relations for elliptical hollow sections, Farhood NOWZARTASH, Magdi MOHAREB, Thin-Walled Structures, 47 (2009), p. 681-691
- [3] SHAPE-THIN 7 user manual, Dlubal Software GmbH, February 2012.



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