

Version September 2011

Add-on Module

# **RF-STEEL BS**

Ultimate Limit State and Serviceability Limit State Design acc. to BS 5950-1 and BS EN 1993-1-1

## **Program Description**

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# I. Introduction

### 1.1 Additional Module RF-STEEL BS

The British Standard BS 5950-1:2000 determines rules for the design, analysis and construction of steel buildings in the United Kingdom. With the add-on module RF-STEEL BS from the company ING. SOFTWARE DLUBAL all users obtain a highly efficient and universal tool to design steel structures consisting of members according to this standard. Furthermore, the design can be carried out according to BS EN 1993-1-1:2005 (Eurocode 3) with consideration of the National Annex for the United Kingdom.

All typical designs of load capacity, stability and deformation are carried out in the module RF-STEEL BS. Different actions are taken into account during the load capacity design. The allocation of designed cross-sections into four classes (plastic, compact, semi-compact and slender) makes an important part of the design according to BS 5950-1:2000. The purpose of this classification is to determine the range in which the local buckling in cross-section parts limits the load capacity so that the rotational capacity of cross-sections can be verified. Further, RF-STEEL BS automatically calculates the limiting width-to-thickness ratios of compressed parts and carries out the classification automatically.

For the stability design, you can determine for every single member or set of members whether buckling is possible in the direction of y-axis and/or z-axis. Lateral supports can be added for a realistic representation of the structural model. All comparative slendernesses and critical stresses are automatically determined by RF-STEEL BS on the basis of the boundary conditions. For the design of lateral torsional buckling, the elastic critical stress that is necessary for the design is calculated automatically. The location where the loads are applied, which influences the elastic critical moment, can also be defined in the detailed settings.

The serviceability limit state has become important for the static calculations of modern civil engineering as more and more slender cross-sections are being used. In RF-STEEL BS, load cases and groups and combinations of load cases can be arranged individually to cover the various design situations. The limit deformations can be defined individually.

Like other modules, RF-STEEL BS is fully integrated into the RFEM 4 program. However, it is not only an optical part of the program. The results of the module can be incorporated to the central printout report. Therefore, the entire design can be easily and especially uniformly organized and presented.

The program includes an automatic cross-section optimization and a possibility to export all modified profiles to RFEM.

Individual design cases make it possible to flexibly analyze separate parts of extensive structures.

We wish you much success and delight when working with our module RF-STEEL BS.

Your ING. SOFTWARE DLUBAL company.



### 1.2 RF-STEEL BS Team

The following people participated in the development of the RF-STEEL BS module:

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### 1.3 Using the Manual

All general topics such as installation, user interface, results evaluation and printout report are described in detail in the manual for the main program RFEM. Hence, we omit them in this manual and will focus on typical features of the add-on module RF-STEEL BS.



During the description of RF-STEEL BS, we use the sequence and structure of the different input and output tables. We feature the described **icons** (buttons) in square brackets, e.g. [Pick]. The buttons are simultaneously displayed on the left margin. The **names** of dialog boxes, tables and particular menus are marked in *italics* in the text so that they can be easily found in the program.

The index at the end of this manual enables you to quickly look up specific terms.



### 1.4 Starting RF-STEEL BS

It is possible to initialize the add-on module RF-STEEL BS in several ways.

### Main Menu

You can call up RF-STEEL BS by the command from the main menu of the RFEM program: Add-on Modules  $\rightarrow$  Design - Steel  $\rightarrow$  RF-STEEL BS.

Additional Module		V VY O HIM I A H	a i m m m p p p p > 0 0 4
Stresses	• @		₫ ¾ • 💽 i 17 ☜ 🚣 🗢 🗊 🐔
<u>S</u> hape Prope		· <i>•</i>	
Design - St <u>e</u>	el 🔹 🔺 🥌	RF-STEEL Surfaces	General Stress Analysis for Surfaces
Design - Cor	c <u>r</u> ete 🕨 🖉	RF-STEEL Surfaces (2003	3) General Stress Analysis for Surfaces
Design - <u>T</u> im	ber 🕨 🗂	RF-STEEL Members	General Stress Analysis for Members
<u>D</u> ynamic		RF-STEEL EC3	Design according to Eurocode 3
Connections			Design according to AISC (LRFD or ASD)
<u>F</u> oundations	• Als	RF-STEEL IS	Design according to IS 800
Stability	•	-	Design according to IS 000
Towers		-	
_	18	RF-STEEL BS	Design according to BS
<u>O</u> thers	•		

Figure 1.1: Main Menu: Additional Modules  $\rightarrow$  Design - Steel  $\rightarrow$  RF-STEEL BS

### Navigator

Further, it is possible to start RF-STEEL BS from the *Data* navigator by clicking on the item Add-on Modules  $\rightarrow$  RF-STEEL BS.

Project Navig	ator	×
🚊 💼 Gu	ide Objects	~
🚊 📥 Ad	lditional Modules	
15	SHAPE-THIN 7 - Section Properties of Thin-walled Sections	
	SHAPE-MASSIVE - Section Properties of Thick-walled Sections	
- 2	RF-STEEL Surfaces (2003) - General Stress Analysis for Surfaces	
- 2	RF-STEEL Surfaces - Stress Analysis for Surfaces	
1	RF-STEEL Members - General Stress Analysis for Steel Members	
- Io	RF-STEEL EC3 - Steel Design according to Eurocode 3	
	RF-STEEL AISC - Steel Design according to AISC (LRFD or ASD)	
- Is	RF-STEEL IS - Steel Design according to IS 800	
- Sia	RF-STEEL SIA - Steel Design according to SIA 263:2003	
1	RF-STEEL BS - Steel Design according to BS	=
···• **	RF-KAPPA - Buckling Analysis for Compression Members	
	RF-LTB - Lateral Torsional Buckling Analysis	
Q.	RF-FE-LTB - Lateral Torsional Buckling Check with Finite Members	
12	RF-EL-PL - Elastic-plastic Design	
	RF-C-TO-T - Limiting Width-Thickness Ratio Check (c/t)	
···· 🕅	PLATE-BUCKLING - FEM Plate Buckling Analysis	
<u>F</u>	VERBAND - Wind Bracings with Stabilisation Loads	
	RF-ASD - Steel Design according to US-Norm AISC ASD	
A	CRANEWAY - Crane Girder Analysis	
0	RF-CONCRETE Surfaces - Reinforced Concrete Design of Surfaces	~
<		
🐴 Data 🏮 I	Display   4	⊳

Figure 1.2: Data Navigator: Additional Modules  $\rightarrow$  RF-STEEL BS



### Panel

RF-STEEL BS CA1 - Steel Desig 🔽 < > LC1 - Vy LC2 - Vz RF-STEEL BS CA1 - Steel Design according to



If results of RF-STEEL BS are already available in the RFEM position, you can set the relevant design case of this module in the list of load cases in the menu bar. The design criterion on members is displayed graphically in the work window of RFEM by using the [Results on/off] button.

The [RF-STEEL BS] button that enables you to start RF-STEEL BS is now available in the panel.

Panel	×
Max Design Ratio [-]	
1.00 0.90 0.80 0.70 0.50 0.50 0.40 0.30 0.20 0.10 0.00	
Max : 0.84 Min : 0.00	
RF-STEEL BS	
📕 🕾 🖄 I	

Figure 1.3: [RF-STEEL BS] button in panel

**RF-STEEL BS** 



# 2. Input Data

The data of the design cases is to be entered in different tables of the module. Furthermore, the graphic input using the function [Pick] is available for members and sets of members.

After the initialization of the RF-STEEL BS module, a new window is displayed. In its left part, a navigator is shown that enables you to access all existing tables. The roll-out list of all possibly entered design cases is located above this navigator (see chapter 7.1, page 51).

If RF-STEEL BS is called up for the first time in a position of RFEM, the following important data is loaded automatically:

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

[Cancel] button you terminate the module without saving data.

You can switch among the tables either by clicking on the individual navigator items of RF-STEEL BS or by using the buttons visible on the left. The [F2] and [F3] function keys can also be used to browse the tables in both directions.

ОК	
Cancel	

-

3

also be used to browse the tables in both directions. Save entered data by the [OK] button and close the module RF-STEEL BS, while by the

### 2.1 General Data

In the table 1.1 *General Data*, members, sets of members and actions are selected for the design. You can specify load cases, load groups and combinations for the ultimate limit state and the serviceability limit state design separately in the corresponding tabs.

### 2.1.1 Ultimate Limit State

	1.1 General Data	
nput Data General Data Materials Cross-sections Lateral Intermediate Supports Effective Lengths - Members Effective Lengths - Sets of Men Nodal Supports Set of Members No. 1 - Cor Member Releases Serviceability Data	Sets:         1         Image: Constraint of the set of th	Design according to         Image: Bit S 5950-1:2000         Image: Bit S 5950-1:2000
	Comment	

Figure 2.1: Table 1.1 General Data, Ultimate Limit State tab



### Design of

You can select both *Members* and *Sets of Members* for the design. If only specific objects are to be designed, it is necessary to clear the check box *All*. By doing so, both input boxes become accessible and you can enter the numbers of the relevant members or sets of members there. With the [Pick] button, you can also select members or sets of members graphically in the RFEM work window. To rewrite the list of default member numbers, select it by double-clicking it, and then enter the relevant numbers.

If no sets of members have been defined in RFEM yet, they can be created in RF-STEEL BS via the [New Set of Members...] button. The familiar RFEM dialog box to create a new set of members opens in which you enter the relevant data.

Designing sets of members has the advantage that selected members can be analyzed to determine the total maxima of the design ratios. In this case, the results tables 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* are displayed additionally.

### Design according to

The list box controls whether the analysis is carried out according to the provisions of the BS 5950-1:2000 or the British National Annex of EN 1993-1-1.

### **Existing Load Cases / Load Groups and Load Combinations**

All design-relevant load cases, load groups and load combinations that were created in RFEM are listed in these two sections. The [**>**] button moves the selected load cases, load groups or combinations to the list *Selected for Design* on the right. Specific items can also be selected by double-clicks. The [**>**] button transfers all items to the list on the right.

If an asterisk (\*) is displayed at load cases or combinations, as you can see e.g. in figure 2.1 at load cases 8 to 10, they are excluded from the design. It signifies that no loads were assigned to these load cases or that they contain only imperfections (as in our example).

Furthermore, it is only possible to select load combinations for which the minimum and maximum values can be determined unambiguously. This restriction is necessary because the calculation of the elastic critical moment at lateral buckling requires the unambiguous assignment of moment diagrams. If an invalid load combination is selected, the following warning appears:

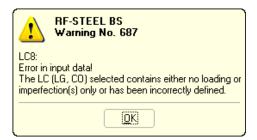


Figure 2.2: Warning when Selecting Invalid LC, LG or CO

A multiple choice of load cases can be done by using the [Ctrl] key, as a routine procedure in Windows. Hence, you can select and transfer several load cases to the list on the right simultaneously.

### **Selected for Design**

**\$** 

The loads selected for the design are listed in the right column. By the [ $\blacktriangleleft$ ] button you can remove the selected load cases, load groups or load combinations from the list. As before, the selection can be executed by double-clicks. The [ $\blacktriangleleft \triangleleft$ ] button removes all items from the list.





G

÷



5

Generally, the calculation of an enveloping *Or* load combination is faster than the analysis of all contained load cases or groups. On the other hand, you must keep in mind the abovementioned restriction: to determine the maximum or minimum values unambiguously, the *Or* load combination must only contain load cases, groups or combinations which enter the combination with the criterion *Constant*. Moreover, the design of an enveloping load combination makes it a bit difficult to retrace the influence of the contained actions.

### 2.1.2 Serviceability Limit State

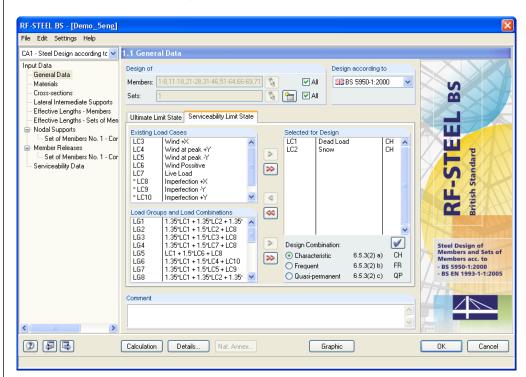


Figure 2.3: Table 1.1 General Data, Serviceability Limit State tab

### **Existing Load Cases / Load Groups and Load Combinations**

All load cases, load groups and load combinations that were created in RFEM are listed in these two sections.

#### Selected for Design

Adding load cases and their groups and combinations to the list for the design, resp. removing them from the list is done in the same way like in the previous register tab (see chapter 2.1.1).

### **Design Combination**

In this dialog section, you can set different limit values that are to be applied for the deflections of combined actions. The relevant limit value for the selected design combination can be assigned as follows: Click the action in the list *Selected for Design* to select it. Then click the blue tick [ $\square$ ] to allocate the selected combination.

You can choose among the following criteria as specified in EN 1990:

- Characteristic (CH)
- Frequent (FR)

1

Quasi-permanent (QP)



The limit values are settled by the standard. They can be modified in the dialog box that controls the details (see figure 3.1, page 29) resp. the parameters of the National Annex (see figure 2.4, page 11).

#### Comment

You can enter some additional notes here to describe the current design case.

### 2.1.3 National Annex (NA)

Nat. Annex...

If the design is to be carried out according to BS EN 1993-1-1, the button [National Annex] is accessible in all input tables. You can use it call up the dialog box *National Annex Settings* that consists of two register tabs.

#### Base

Base Stainless Steel (EN 1993-1-4)		
Partial Factors acc. to 6.1, Note 2B		Serviceability Limits (Deflections) acc. to 7.2
- For Resistance of Cross-sections - For Resistance of Members to Buckling (For design according 6.3 an/or in case of activation for cross section resistance detection)	γмо: 1.000 📩 γм1: 1.000 🛬	Combination of Actions (Table A1.4 of EN 1990):           Cantilevers           CH : Characteristic         L / 300 +         Lo / 150 +           FR : Frequent         L / 200 +         Lo / 100 +
<ul> <li>For Resistance of Cross-sections to Fracture due to Tension</li> </ul>	γм2: 1.100 📩	QP: Quasi-permanent L / 200 🛧 L <sub>o</sub> / 100 束
Fire Design Settings		Shear acc. to 6.2.6(3) and Shear Buckling acc. to EN 1993-1-5
Partial Factor for Fire Situation	γм,fi: 1.000 🚔	Factor η: 1.200
Parameters for Lateral-torsional Buckling Imperfection Coefficients of Lateral-torsional Buckling Curves acc. to Table 6.3:	Determine Lateral-tors Curves for 6.3.2 and 6	6.3.3:
Imperfection Coefficient αLT           Buckling Curve         a : 0.210 + b : 0.340 + c : 0.490 + d : 0.760 +	<ul> <li>Always according to General Case (Const Always according to Rolled or Uniformly Cross-sections</li> <li>If Possible, accordin Otherwise accordin</li> </ul>	servative) (Non-applicable if Bending around z-Axis) o Eq. (6.57) Equivalent Buckling Curve according to [5] ng to Eq. (6.56) [5] Naumes, J., Strohmann, I., Ungermann, D., Sedlacek, G.; Die neuen Stabilitätsrachweise im Stahlbau nach Eurocode 3.
Parameters for Φ <sub>LT</sub> acc. to 6.3.2.3(1):           Rolled         Welded           I-Sections         I-Sections           λLT,0:         0.400 (m)         0.200 (m)           β:         0.750 (m)         1.000 (m)	Determine Interaction F according to Method: 1 according to Anni 2 according to Anni	Use Adapted Method according to [6] (Enable Double Bending)
Les Factor f for Modification of XLT according to 6.3.2.3(2)		

Figure 2.4: Dialog box National Annex Settings, tab Base

In the dialog sections you can check the *Partial Factors*, the *Serviceability Limits* as well as the *Parameters for Lateral-torsional Buckling* and adjust them, if necessary.



In the dialog section *General Method according to 6.3.4*, it is additionally possible to decide if you want to perform the stability analysis always in accordance with [1], section 6.3.4. (According to the German National Annex, the general method is only allowed to be used for I-shaped cross-sections. By activating the option *Enable Also for Non I-Sections* you can use the method also for other cross-sections.)

In addition, it is possible to perform the stability analysis using the European lateraltorsional buckling curve according to NAUMES [5]. In his dissertation from November 2009, he completed the "General method for lateral and lateral torsional buckling of structural components" design according to EN 1993-1-1:2007 clause 6.3.4 by additional transverse



bending and torsion. This method is available in RF-STEEL BS in order to design unsymmetrical cross-sections as well as tapered members and sets of members with biaxial bending.

According to section 6.3.4 (4), the reduction factor  $\chi_{op}$  is to be calculated

- a) as minimum value of the values for buckling according to 6.3.1 or  $\chi_{LT}$  for lateraltorsional buckling according to 6.3.2 by means of the slenderness degree  $\chi_{op}$ , or
- b) as a value that is interpolated between  $\chi$  and  $\chi_{\text{LT}}$  (see also equation (6.66) of EN 1993-1-1).

As the method according to NAUMES is based on the standardized European lateral-torsional buckling curve taking into account the modified imperfection factor  $\alpha^*$ , the interaction between local buckling and lateral-torsional buckling according to equation (6.66) can be omitted. In the first step, the calculation is carried out separately for the principal and the secondary load-bearing plane.

Calculation						
Principal plane		Secondary plane				
$\alpha_{Ed}(x) = \frac{\chi_{LT}(x) \cdot \alpha_{ult,k}(x)}{\gamma_{M1}} \ge 1$		$\beta_z(x) = \frac{M_{z,Ed}(x)}{M_{z,Rd}(x)} \cdot (1 - q_{Mz})$				
	Design					
simplified		accurate				
$ riangle n_R = 0.9$	$\triangle n_R = 1 - \frac{1}{\alpha}$	$\frac{1}{_{Ed}(x)} \cdot \left[1 - \frac{1}{\alpha_{Ed}(x)}\right] \cdot \chi^2_{LT}(x) \cdot \overline{\lambda}^2_{LT}(x)$				
	$\frac{1}{\alpha_{Ed}(x)} + \beta_z(x) \le \triangle n_R$					

Figure 2.5: Calculation run for the method according to NAUMES

In the second step, the design criterion  $\Delta n_R$  is determined. Finally, the design concerning the summation of the design ratios for the principal and the secondary load-bearing plane is performed and compared to the design criterion  $\Delta n_R$ .

Moment diagram $M_z$	$q_{M_z}$
	$q_{M_z} = 0.21 \cdot (1 - \psi_z) + 0.36 \cdot (0.33 - \psi_z) \cdot \frac{1}{\alpha_{crit}} \le \frac{1}{\alpha_{crit}}$
$\max M_{z,Ed} $	$q_{M_z} = \frac{1}{\alpha_{crit}} \cdot \left( 1 - \frac{\pi^2 E I_z \cdot \max \delta_y }{l^2 \cdot \max M_{z,Ed} } \right)$
$\max M_{z,Ed} $	
	$q_{M_z} = 0.18 \cdot \frac{1}{\alpha_{crit}}$
	$q_{M_z} = 0.03 \cdot \frac{1}{\alpha_{crit}}$

Figure 2.6: Determination of the moment factor  $\ensuremath{\mathsf{q}_{\mathsf{Mz}}}$ 



### **Stainless Steel**

RF-STEEL BS also allows for the design of structural components made of stainless steel according to EN 1993-1-4 [4].

In the second tab of the dialog box *National Annex Settings* you find the relevant *Partial Factors* and *Parameters for Stability Design*.

tional Annex Settings - BS EN 1993-1-1			<u> </u>
Base Stainless Steel (EN 1993-1-4)			
Partial Factors acc. to 5.1			
- For Resistance of Cross-sections	умо : 1.100 🚔		
<ul> <li>For Resistance of Members to Buckling (Assessed for Proofs in Clause 6.3)</li> </ul>	ум1 : <u>1.100</u>		
- For Resistance of Cross-sections to Fracture due to Tension	ум2 : 1.250 <u>×</u>		
Shear according to 5.6(2) and Shear Buckling Factor η: 1.200 💌			
Parameters for Stability Design			
Imperfection Coefficients $\alpha$ and Values $\lambda_0$ for Centric Compression according to Table 5.3	Imperfection	Parameter for Φ	
Buckling	Coefficient a	Parameter for Φ λ0	
- Cold Formed Open Sections:	0.490 ≑	0.400 ≑	
- Hollow Sections (Welded or Seamless):	0.490 ≑	0.400 ≑	
- Welded Open Sections (around Major Axis):	0.490 ≑	0.200 ≑	
- Welded Open Sections (around Minor Axis):	0.760 🚔	0.200 ≑	
Torsional and Lateral-torsional Buckling			
- All Structural Members:	0.340 🚔	0.200 🚔	
Imperfection Coefficients $\alpha_{LT}$ for Lateral-torsio Buckling according to 5.4.3.1(1)	nal Imperfection Coefficient αι τ		
- Cold Formed Sections and Hollow Sections (Welded and Seamless):	0.340		
- Welded Open Sections and Other Sections:	0.760 🚔		
2 · · · · · · · · · · · · · · · · · · ·			OK Cancel

Figure 2.7: Dialog box National Annex Settings, tab Stainless Steel (EN 1993-1-4)



### 2.2 Materials

This table is divided into two parts. The materials for the design are listed in the upper part. In the lower part, the *Material Properties* of the current material are displayed, i.e. the material whose line is selected in the upper table.

Materials that won't be used in the design appear gray in color. Materials that are not allowed are highlighted in red. Modified materials are displayed in blue.

The material properties required to calculate the internal forces in RFEM are described in detail in the RFEM manual, chapter 5.3. The design-relevant material characteristics are stored in the global material library. Those are automatically set as default.

The units and decimal places of the material properties and stresses can be edited from the main menu **Options**  $\rightarrow$  **Units and Decimal Places** (see chapter 7.4, page 56).

'A1 - Steel Design according to 💙	1.2 Mat	erials					
nput Data		А		В			
General Data	Material	Material					
Materials	No.	Description		Comment			
Cross-sections	1	Grade S 275 Steel   BS 5950-1:20					
- Lateral Intermediate Supports	2	Grade S 355 Steel   BS 5950-1:200					
- Effective Lengths - Members							
- Effective Lengths - Sets of Men	ſ				۱		
Nodal Supports	l					5	
Set of Members No. 1 - Cor	No. of the local sector of						
Member Releases		l Properties					
- Set of Members No. 1 - Cor		Relevant				^	
- Serviceability Data		lulus of Elasticity	E	205000.000			
		ar Modulus	G	78846.200	MPa		
		son's Ratio	Д	0.300			
		Weight	γ		kN/m <sup>3</sup>		
		fficient of Thermal Expansion	α	1.2000E-05	1/°C		
		ial Safety Factor	γм	1.00			
		n Relevant					
		d Strength	Ру	275.000		Material	No. 1 Used in
		. Structural Thickness	ti	1.60		Cross-	
		d Strength	Py	265.000		sections	: 1-3,6,7,10,12,13,15
		. Structural Thickness	t2	4.00			
		d Strength	Ру	255.000		Member	s: 1-8,11-18,21-28,31-46,51-64
		. Structural Thickness	ta 🛛	6.30		Sets of	1
		d Strength	Ру	245.000		Member	s: 1
		. Structural Thickness	t4	8.00	cm	Σ Lengt	h: 466.46 [m]
		d Strength	Ру	235.000		-	
	Max	. Structural Thickness	ts .	10.00	cm	Σ Mass:	14.595 [t]
>							

Figure 2.8: Table 1.2 Materials

#### **Material Description**

The materials that have been defined in RFEM are set by default. You can also enter materials manually here. If the *Material Description* corresponds to an entry in the material library, RF-STEEL BS automatically imports the relevant material properties.

To select a material from the list, place the cursor in column A and click on the  $[\Psi]$  button or press the [F7] function key. A list is opened that you can see on the left. As soon as you have chosen the appropriate material, the material characteristics are updated in the table below.

According to the design concept of British Standard, the list of materials includes only materials from the category **Steel**. How to import materials from the library is described below.

Basically, it is not possible to edit the material properties in RF-STEEL BS.

Grade S 275 Ste	el   BS 5950-1:20	
Grade S 275 Steel	BS 5950-1:2000	~
Grade S 355 Steel	BS 5950-1:2000	
Grade S 460 Steel	BS 5950-1:2000	
Grade 43 Steel	BS 4360:1986	
Grade 50 Steel	BS 4360:1986	
Grade 43 Steel	BS 5950:1990	
Grade 50 Steel	BS 5950:1990	
Grade 55 Steel	BS 5950:1990	
Grade S 275 Steel	BS 5950:1990	_
Grade S 355 Steel	BS 5950:1990	×



### **Material Library**

A considerable amount of materials is stored in the library. Open the library via menu

#### Edit $\rightarrow$ Material Library

or by clicking on the button visible on the left.

Filter Choice	Material to Select							
Material Catalogue	Grade S 275 Steel		BS 5950-1:2					
Material Category:	Grade S 355 Steel		BS 5950-1:2					
Steel 💌	Grade S 460 Steel Grade 43 Steel		BS 5950-1:2 BS 4360:19					
Code Group:	Grade 50 Steel		BS 4360:19					
•	Grade 43 Steel			BS 5950:1990				
BS 💌	Grade 50 Steel		BS 5950:19					
Code:	Grade 55 Steel		BS 5950:19					
	Grade S 275 Steel Grade S 355 Steel			BS 5950:1990 BS 5950:1990				
All	Grade S 450 Steel		BS 5950:19					
			55 5556.15					
-								
Show:								
					4			
Materials of 'Old' Codes								
	1 I I I I I I I I I I I I I I I I I I I		1		X			
	🔁 🖻 🛃				X			
🗌 Favorites Only 🖉	1		Grade S 275 S	Steel   BS 59	50-1:200			
Favorites Only	1 P 2		Grade S 275 S	Steel   BS 59:				
Favorites Only  Favorites Only  Material Constants  RSTAB Relevant	1	E						
Favorites Only		E	205000.000	MPa				
Favorites Only Material Constants <b>RSTAB Relevant</b> Modulus of Elasticity		G		MPa				
Favorites Only Favorites Only  Favorites Onl		G A	205000.000 78846.200 0.300	MPa				
Favorites Only  Favorites Only  Aterial Constants  RSTAB Relevant  Modulus of Elasticity  Shear Modulus  Poisson's Ratio		G	205000.000 78846.200 0.300	MPa MPa kN/m <sup>3</sup>				
Favorites Only  Favorites Only  Atterial Constants  RSTAB Relevant  Modulus of Elasticity  Shear Modulus  Poisson's Ratio Unit Weight		G μ γ	205000.000 78846.200 0.300 78.50	MPa MPa kN/m <sup>3</sup>	50-1:200			
Favorites Only     Favorites Only      Material Constants      RSTAB Relevant      Modulus of Elasticity      Shear Modulus      Poisson's Ratio      Unit Weight      Coefficient of Thermal Expansi      Partial Safety Factor		G μ γ α	205000.000 78846.200 0.300 78.50 1.2000E-05	MPa MPa kN/m <sup>3</sup>				
Favorites Only     Favorites Only      Material Constants      RSTAB Relevant      Modulus of Elasticity      Shear Modulus      Poisson's Ratio      Unit Weight      Coefficient of Thermal Expansi      Partial Safety Factor		G μ γ α	205000.000 78846.200 0.300 78.50 1.2000E-05	MPa MPa kN/m <sup>3</sup> 1/°C				
Favorites Only Favorites Only  Atternal Constants  RSTAB Relevant  Modulus of Elasticity  Shear Modulus  Poisson's Ratio  Unit Weight  Coefficient of Thermal Expansi  Partial Safety Factor  Design Relevant		G μ γ α γΜ	205000.000 78846.200 0.300 78.50 1.2000E-05 1.00	MPa MPa kN/m <sup>3</sup> 1/°C MPa				
Favorites Only Favorites Only  RSTAB Relevant  Modulus of Elasticity Shear Modulus Poisson's Ratio Unit Weight Coefficient of Thermal Expansi Partial Safety Factor Design Relevant Yield Strength		G μ γ α γΜ Ρy	205000.000 78846.200 0.300 78.50 1.2000E-05 1.00 275.000	MPa MPa kN/m <sup>3</sup> 1/*C MPa cm				
Favorites Only Favorites Only  Atterial Constants  RSTAB Relevant  Modulus of Elasticity Shear Modulus  Poisson's Ratio Unit Weight Coefficient of Thermal Expansi Partial Safety Factor  Design Relevant  Yield Strength Max. Structural Thickness		G μ γ α γΜ Ρy t1	205000.000 78846.200 0.300 78.50 1.2000E-05 1.00 275.000 1.60	MPa MPa kN/m <sup>3</sup> 1/*C MPa cm MPa				
Favorites Only Favorites Only  RSTAB Relevant Modulus of Elasticity Shear Modulus Poisson's Ratio Unit Weight Coefficient of Thermal Expansi Partial Safety Factor Design Relevant Yield Strength Max. Structural Thickness Yield Strength		G μ γ α γΜ Ρy t1 Ρy	205000.000 78846.200 0.300 78.50 1.2000E-05 1.00 275.000 1.60 265.000	MPa MPa kN/m <sup>3</sup> 1/°C MPa cm MPa cm				
□ Favorites Only         ■ Favorites Only         ■ RSTAB Relevant         Modulus of Elasticity         Shear Modulus         ■ Poisson's Ratio         Unit Weight         Coefficient of Thermal Expansi         ■ Partial Safety Factor         ■ Design Relevant         Yield Strength         Max. Structural Thickness         Yield Strength         Max. Structural Thickness		G μ γ α γΜ Ρy ξ1 Ρy ξ2	205000.000 78846.200 0.300 78.50 1.2000E-05 1.00 275.000 1.60 265.000 4.00	MPa MPa kN/m <sup>3</sup> 1/*C MPa cm MPa cm MPa cm				

Figure 2.9: Material Library Dialog Box

In the section *Filter Choice*, the material category **Steel** is set by default. In the list *Material to Select* which is located on the right, you can select a particular material, and in the lower part of the dialog box you can check its characteristic values.

After clicking on [OK] or pressing the [] key, the material is taken over to the table 1.2 *Materials* of RF-STEEL BS.

Chapter 5.3 of the RFEM manual explains in detail how materials can be filtered, added to the library or newly classified.

You can also select materials of the categories *Cast Iron* and *Stainless Steel* from the library. However, please reflect whether those materials are covered by the design rules of British Standard.

OK



### 2.3 Cross-Sections

This table controls the cross-sections that are to be designed. The parameters of the optimization can be defined here as well.

### **Coordinate System**

The sectional coordinate system yz of RF-STEEL BS corresponds to the one of RFEM (see image in figure 2.10). The y-axis is the <u>major</u> principal axis of the cross-section, the z-axis the <u>minor</u> axis. This coordinate system is used for both the input data and the results.

CA1 - Steel Design according to 💙	1.3 Cro	ss-secti						
Imput Data General Data Materials Cross-sections Lateral Intermediate Supports Effective Lengths - Members Effective Lengths - Sets of Mem Nodal Supports Nodal Supports Set of Members No. 2 - Set Member Releases Later Members No. 2 - Set Serviceability Data Results Design by Load Case	No. 1 2 3	A Material No. 1 1 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1	B Cross-section Description [mm] IPE 450 (British IPE 400 (British UBP 254x254x7 UBP 203x203x4 IPER 450 (Britis UBP 203x203x4 GR0 60x5.0 (Bri Circle 24 UBP 254x254x6 IPE 350 (British IPE 350 (British	C Cross-section Type for Classification I-shape rolled I-shape rolled I-shape rolled I-shape rolled I-shape rolled Box Rolled Box Rolled Round Bar I-shape rolled	D Max. Design Ratio 1.09 0.62 0.46 0.07 0.09 0.19 0.05 0.04 0.02 0.04 0.02		F 2) 2	1 - IPE 450 (British Steel)
Design by Load Lase Design by Loads Lase Design by Set of Members Design by Member Design by Member Governing Internal Forces by M Governing Internal Forces by Si Member Slendernesses Parts List by Member Parts List by Member	17	1	L 150x90x12 (Br	Angle General			8) 8)	(m Cross-section No. 1 Used in Members: 1,2,11,12,21,22,31,32,39,40 Sets of Members: 2 2 Length: 48.00 [m] 2 Mass: 3,723 [t]
( )			2) The cross-si optimal section	ection will be optimized of the table is sought	l. Therefore th out.	e most (	۵ 🐧	Material: 1 - Steel S 355

Figure 2.10: Table 1.3 Cross-Sections

### **Cross-Section Description**

When you open this table, the sections that were defined in RFEM are set by default, including the assigned material numbers.

The cross-sections can be changed any time for the design. The description of a modified cross-section is highlighted in blue color.

In order to edit a cross-section, enter the new description in the corresponding line or select the new section from the library. Open the database by clicking on the [Library] button. Alternatively, place the cursor in the corresponding line and click on the [...] button or press the [F7] key. The library opens which is already familiar from RFEM (see figure 2.11).

Chapter 5.13 of the RFEM manual describes in detail how cross-sections can be selected from the library.





Rolled Cross-sections	Welded Cross-sections	Solid Cross-sections
ICT	ITT	I T L T
LOO	TTL	I I O L
•- ~~ 1	LOC	
Combined Cross-sections	I T O	
IIIT	$\nabla$ <b>I I</b>	u I T
ר אר II	ΠΙΙ	User-defined Cross-sections
Į I I	ī + ·	6
1 I DI	- 1 l	Cross-section Programs
••	L	E



If the cross-sections are different in RF-STEEL BS and RFEM, both cross-sections are shown in the graphic window next to the table. The internal forces from RFEM are then used for the stress design of the cross-section that is set in RF-STEEL BS.

### **Tapered Member**

In case of a tapered member with different cross-sections at the member start and member end, both cross-section numbers are stated in two lines, following the definition in RFEM.

You can design tapered members in RF-STEEL BS if the following condition is fulfilled: an equal number of stress points is required at both member ends: For example, the normal stresses are calculated from the moments of inertia and from the centroidal distances of the stress points. If the start and end cross-sections of the tapered member have different numbers of stress points, RF-STEEL BS cannot interpolate the intermediate values. An error message appears before the calculation:

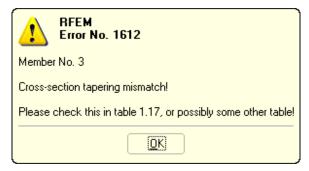
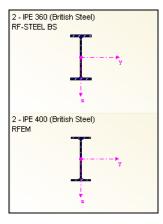


Figure 2.12: Warning in Case of Incompatible Cross-Sections

To check on the stress points of the cross-section, you can display them including their numbers: Select the cross-section in the table 1.3 and click on the [Info] button. The dialog box Info about cross-section appears (see figure 2.13).



0



### Info about Cross-Section

There are different display options for stress points and c/t cross-section parts in this dialog box.

Cross-section Value Description	Symbol	Value	Unit	^	IPE 450 (British Steel)	
)epth	d	450.0	mm			
/idth	Ь	190.0	mm			
/eb thickness	tw	9.4	mm			
lange Thickness	tr	14.6	mm			
illet radius	r	21.0	mm		190.0	
Cross-section area	A	9880.0	mm <sup>2</sup>		+ 130.0	•
Shear area	Av	4642.4	mm <sup>2</sup>			
Shear area	Az	3975.5	mm <sup>2</sup>			
hear area according to EC 3	Av.v	5833.8	mm <sup>2</sup>		14.6	
hear area according to EC 3	Av.z	5082.4	mm <sup>2</sup>			
Web area	Aweb	3955.5	mm <sup>2</sup>			
Plastic shear area	Apl,y	5548.0	mm <sup>2</sup>			
Plastic shear area	Apl,z	4092.8	mm <sup>2</sup>			
Moment of inertia	ly	3.374E+08	mm <sup>4</sup>			
Moment of inertia	lz	1.676E+07	mm <sup>4</sup>		420.0	
Governing radius of gyration	fy	185.0	mm		45	y .
Governing radius of gyration	ſz	41.2	mm			
Polar radius of gyration	fo	189.5	mm			
Radius of gyration of flange plus 1/5 of we	fzg	47.2	mm		9.4	
/olume	v	9880000.0	mm <sup>3</sup> /m			
Weight	wt	77.6	kg/m			
Surface	ASurf	1.605	m <sup>2</sup> /m			
Section factor	Am/V	162.464	1/m			
Forsional constant	J	667000.0	mm <sup>4</sup>		÷	
Warping constant	Cw	7.940E+11	mm <sup>6</sup>		Z	
Elastic section modulus	Sv	1500000.0	mm <sup>3</sup>			
Elastic section modulus	Sz	176000.0	mm <sup>3</sup>			
Warping constant moment	Sw	3.839E+07	mm <sup>4</sup>			
Statical moment of area	Qv	851000.0	mm <sup>3</sup>			
Statical moment of area	Qz	65882.5	mm <sup>3</sup>			
Normalized warping constant	Wne	20681.5	mm <sup>2</sup>			[m
Warping statical moment	Qw	1.434E+07	mm <sup>4</sup>		🖽 📼 🔜 Stress Points	
Plastic section modulus		1702000.0	mm <sup>3</sup>			
Plastic section modulus	Zy Zz	276380.0	mm <sup>3</sup>		🔲 🔝 👼 c/t-Parts	5
Plastic warping constant moment	Zw	5.737E+07	mm <sup>4</sup>	~		

Figure 2.13: Info about Cross-Section Dialog Box

The currently selected cross-section is displayed in the right part of the dialog box. The various buttons below have the following functions:

Button	Function
I	The stress points are switched on and off.
	The cross-section parts (c/t) are switched on and off.
123	The numbering of stress points or cross-section parts (c/t) is switched on and off.
	The details of stress points or cross-section parts (c/t) are displayed.
×	The dimensioning of the cross-section is switched on and off.
Ĵ.⇒	The principal axes of the cross-section are switched on and off.

Table 2.1: Buttons for Cross-Section Graphics



### **Cross-Section Type for Classification**

In this column, the various cross-section types are listed which are applied for the design (e.g. I-shape rolled or welded, box, round bar etc.)

	A	В	С	D	E	F	18 - TU 150/10/50/5/10/0
Section	Material	Cross-section	Cross-section Type	Opti-			
No.	No.	Description [mm]	for Classification	mize	Remark	Comment	
1	1	📕 IPE 450 (British S	I-shape rolled				
2	1	IPE 400 (British S	I-shape rolled				
3	1	📕 IPE 400 (British S	I-shape rolled				
6	1	UBP 254x254x7	I-shape rolled				
7	1	UBP 203x203x4	I-shape rolled				
9	2	📃 IPER 450 (British	I-shape rolled				2 9 9 5.0 v
10	1	UBP 203x203x5	I-shape rolled				₽ 1 <u>50</u>
12	1	📃 QRO 80x5,0 (Briti	Box Rolled				
13	1	Circle 24	General				, <b>™</b>
15	1	UBP 254x254x6	I-shape rolled				↓ ↓ ↓
16	1	📕 IPE 360 (British S	I-shape rolled				2. <del>2</del>
17	1	🔲 L 150x90x12 (Brit	Angle		8)		+-+
18	2	TU 150/10/50/5	General		8)		
							[11]
							(1)
							Cross-section No. 18 Used
							Members:
							Sets of
							Members: -
							Σ Length: 0.00 [m]
							Σ Mass: 0.000 [t]

Figure 2.14: Cross-section Types for Classification

### Max. Design Ratio

This column is only displayed after RF-STEEL BS has designed the cross-sections. It is useful to decide whether to carry out an optimization. The values and the colored relation scales in this column indicate which cross-sections have a low design ratio and therefore are over-sized, resp. which are overstrained and therefore are too weak.

#### Optimize

Every cross-section can be optimized. During the optimization process, the cross-section within the same group of cross-sections is determined on the basis of the internal forces from RFEM which fulfills best the maximum design ratio. Figure 2.10 shows how the optimization of a particular cross-section is set by ticking the corresponding box in column D.

The maximum allowable design ratio for the optimization is controlled in the *Details* dialog box, see chapter 3.1. Further information on the optimization of cross-sections can be found in chapter 7.2 on page 53.

#### Remark

....

In this column, the references to footnotes (below the list of cross-sections) are shown.

If the message *Non-permissible Cross-Section No. XX* appears before the design, then this is due to a cross-section which is not contained in the cross-section library. It may be a user-defined cross-section or a cross-section that was not calculated in the module SHAPE-THIN. Via the [...] button in column B *Cross-section Description*, you can set a cross-section that is suitable for the design (see figure 2.11 with following remarks).



### 2.4 Lateral Intermediate Supports

In this table, lateral intermediate supports on members can be defined. The program always assumes these supports as perpendicular to the minor axis z (see figure 2.10) of the cross-section. Hence, it is possible to change the effective lengths of the member that are important for the design of column buckling and lateral torsional buckling.



Please note that lateral intermediate supports are considered as forked supports for the design.

CA1 - Steel Design according to 🔽	1.4 Lat	eral Inter	mediate S	upports										
Input Data		A	В	C	D	E	F	G	Н		J	K	L	
- General Data	Member No.	Lateral	Length						liate Supp					
- Materials		Supports	L [m]	Number	×1	×2	X3	84	×5	X6	87	X8	X9	
- Cross-sections	2	×	6.000		0.500									
Lateral Intermediate Supports	3		3.011	2	0.333	0.667								-
Effective Lengths - Members			3.011	2	0.333	0.667								-
Effective Lengths - Sets of Men	5		6.274	3	0.250	0.500	0.750							-
Nodal Supports Set of Members No. 2 - Set			6.274		0.230	0.300	0.730							-
Set or Members No. 2 - Set     Member Beleases	7	H	3.262											-
Set of Members No. 2 - Set			0.202										_	
Serviceability Data					🗹 Relative	ly (0 1)							•	C
	Memb Numb Positic	I Supports E: er Length er of Lateral on of Lateral on of Lateral	Intermediate Support No.	1	L n X1 X2		6.274 3 0.250 0.500	m		-				
		on of Lateral			X3		0.750				<b>₽</b> X			
												×1		(

Figure 2.15: Table 1.4 Lateral Intermediate Supports

In the upper part of this table, up to nine lateral intermediate supports can be created per member. The lower part of the table displays the summary of the entered data for every single member.

Lateral intermediate supports can be defined either by directly entering the distances from the member start or by specifying the support locations *Relatively*. For the latter, it is necessary to tick the associated check box below the list. The locations of the supports are then calculated from the member lengths and the defined intervals.

You have to be very careful if the model contains cantilever beams. Intermediate supports divide the member into several parts for the design. Therefore, intermediate supports are to be avoided for cantilever beams because they would imply statically underdetermined pieces with fork-type supports on only one side each.



### 2.5 Effective Lengths - Members

The table 1.5 consists of two parts so that a good overview of the data is provided. In the upper table, the effective length factors  $K_y$  and  $K_z$ , the effective lengths  $KL_y$  and  $KL_z$ , the equivalent uniform moment factor  $m_{LT}$ , lateral-torsional factor  $K_{LT}$  and the effective length for lateral-torsional buckling  $KL_{LT}$  are summarized for every member. In the lower part of this table, detailed information on the member that is selected in the upper table is displayed. The lower table contains all information about the relevant lengths of this member.

🔉 - Steel Design according to 🗸	1.5 Eff	ective Le	ngths - I	Members										
nput Data		A	В	С	D	E	F	G	Н		J	K	L	ב
- General Data	Member No.	Buckling		g about Major A			) about Mino			Lateral-torsic			_	
- Materials	NU.	Possible	Possible		Ly [m]	Possible	Kz	KL <sub>z</sub> [m]	Possible		Klt	KLLT [m]	Commer	nt
- Cross-sections	1	×	×	1.000	6.000	×	1.000	3.000	×	1.000	1.000	3.000		_
<ul> <li>Lateral Intermediate Supports</li> </ul>	2	×	×	1.000	6.000	×	1.000	6.000	×	1.000	1.000	6.000		_
Effective Lengths - Members	3	×	×	1.000	3.011	×	1.000	1.004	×	1.000	1.000	1.004		_
<ul> <li>Effective Lengths - Sets of Men</li> </ul>	4	×	×	1.000	3.262	×	1.000	3.262	×	1.000	1.000	3.262 1.568		_
Nodal Supports	5	×	×	1.000	6.274 6.274	×	1.000	1.568	×	1.000	1.000	6.274		_
Set of Members No. 2 - Set	7	X	X	1.000	3.262	X	1.000	3.262	X	1.000	1.000	3.262		
Member Releases			-	1.000	3.262		1.000	3.262		1.000	1.000	3.262		
Set of Members No. 2 - Set Serviceability Data												2	<b>(</b>	1
	Setting	s for Men	nber No	. 1						IPE 450 (Bri	tish Steel)			
		section				1.	IPE 450 (Brit	ish Steel)			. 190	.0		
	Length	1			L		6.000					1		
	Buckli	ng Possible					×			-				
	🖃 Buckli	ng about A:	kis y Possil	ble			×				14.6			
	Effe	ctive Leng	h Factor		Ky		1.000	1						
	Effe	ctive Leng	:h		KLy		6.000	l m		0				
	🖃 Buckli	ng about A:	kis z Possil	ble			×			450.0			Þ.,	
		ctive Leng			Kz		1.000					9.4	- 1	
		ctive Leng			KLz		3.000					0.4		
		I-torsional B					×							
		iivalent Unil			MLT		1.000							
		ctive Leng			Klt		1.000							
			th for Later	ral-torsional Bu	KLLT		3.000	m				-		
	Comm	ent											[	m
	Set In	puts for Me	mbers No.	:				r an	🗹 All	0		X		à

Figure 2.16: Table 1.5 Effective Lengths - Members

The effective lengths for the column buckling about the minor principal axis are automatically loaded from the previous table 1.4. If a member is divided into different lengths by lateral intermediate supports, then no values are displayed in the corresponding columns D and G of table 1.5.

It is possible to change the buckling length coefficients both in the summary table in the upper part and in the detailed settings in the lower part. The data of the corresponding part of this table is then updated automatically. The buckling length of a member can also be defined graphically by using the function [Pick].

The tree structure in the lower part of the *Settings for Member* table contains the following parameters:

- Cross-section
- Length (actual length of the member)
- Buckling Possible for member (cf column A)
- Buckling/Lateral-torsional Buckling Possible (cf columns B, E and H)
- Buckling about Mayor Axis y Possible (buckling lengths, cf columns C and D)
- Buckling about Minor Axis z Possible (buckling lengths, cf columns F and G)
- Lateral-torsional Buckling Possible (lateral-torsional length, cf columns H to K)

....



It is also possible to modify the *Buckling Length Coefficients* in the relevant directions and decide whether the buckling design is to be executed. If a buckling length coefficient is changed, the respective effective member length is modified automatically.

The effective length factors of the members can also be defined in a special dialog box which is called by the button [Select Effective Length Factor] below the upper table.

Select Effective Length Factor	×
Buckling around Axis y	Buckling around Axis z
O Ky = 0.7	O K <sub>2</sub> = 0.7
○ K <sub>y</sub> = 0.85	○ K <sub>z</sub> = 0.85
O Ky = 0.85	O K <sub>2</sub> = 0.85
• Ky = 1.0	• K <sub>2</sub> = 1.0
O Ky = 1.2	O K <sub>z</sub> = 1.2
О Ку = 1.5	O Kz = 1.5
O Ky = 2.0	O K <sub>2</sub> = 2.0
User-defined	Uger-defined
Import from Additional Module RF-STABILITY     (Eigenvalue Analysis)	<ul> <li>Import from Additional Module RF-STABILITY (Eigenvalue Analysis)</li> </ul>
RF-STABILITY-Case:	RF-STABILITY-Case:
Buckling Shape No.: 0 (\$)	Buckling Shape No: 00
Export Effective Length Factor Ky: 1.000 🗇	Export Effective Length Factor K2: 1.000 🗇
Ø	OK Cancel

Figure 2.17: Dialog box: Select Effective Length Factor

The predefined values of the effective length factor **K** corresponds to the following definitions:

- ${\rm K} = 0.7 \qquad {\rm effectively\ held\ in\ position\ at\ both\ ends\ +\ effectively\ restrained\ in\ direction\ at\ both\ ends}$
- K = 0.85 effectively held in position at both ends + partially restrained in direction at both ends
- K = 0.85 effectively held in position at both ends + restrained in direction at one end
- K = 1.0 effectively held in position at both ends + not restrained in direction at either end
- K = 1.2 effectively held in position and restrained in direction at one end + not held in position and effectively restrained in direction at other end
- K = 1.5 effectively held in position and restrained in direction at one end + not held in position and partially restrained in direction at other end
- K = 2.0 effectively held in position and restrained in direction at one end + not held in position and not restrained in direction at other end

The effective lengths for buckling can also be imported from the RFEM add-on module RF-STABILITY.



### **Buckling Possible**

For the stability design of the buckling and lateral-torsional buckling, it is necessary for the member to transfer compression forces. Members that cannot transfer compression forces due to their definition (e.g. tension members, elastic foundations, rigid couplings) are a priori excluded from the stability design in RF-STEEL BS. In such a case, a corresponding comment is displayed in the column *Comment* for this member.

The column *Buckling Possible* makes it possible to classify specific members as compression members or, alternatively, to exclude them from the design. Hence, the check boxes in column A and also in table *Settings for Member No.* control whether the input options for the buckling length parameters are accessible for a member.

### Buckling about Axis y resp. Axis z

The columns *Buckling Possible* control whether members are prone to buckling about their axes y and/or axes z. The axis y represents the "major" principal member axis, the axis z the "minor" principal member axis. The buckling length factors  $K_y$  and  $K_z$  can be freely chosen for the buckling about the major and minor axes.

<u>G</u>raphic

The orientation of the member axes can be checked in the cross-section graphics of table 1.3 *Cross-Sections* (see figure 2.10). In the RFEM work window which is accessible any time via the [Graphic] button, you can display the local member axes from the *Display* navigator.

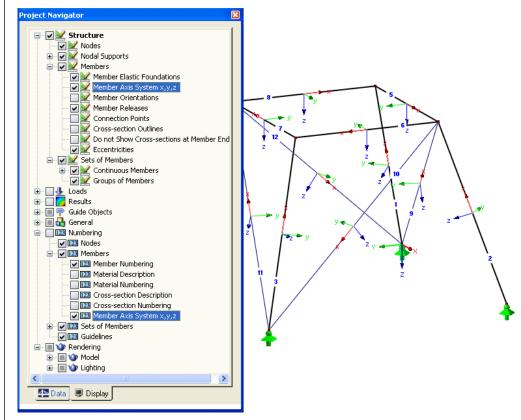


Figure 2.18: Displaying the Local Member Axes in the Display Navigator of RFEM

If buckling is possible about one or both member axes, the precise values can be entered in columns C and D resp. F and G or in table *Settings for Member No*. below.

If you define the buckling length coefficient *K*, the buckling length *KL* is determined by multiplying the member length *L* with this buckling length coefficient.

....

Via the [...] button at the end of the *KL* input fields, you can select two nodes in the RFEM work window graphically. Their distance then defines the buckling length.



### Lateral-Torsional Buckling

Column H controls whether a lateral torsional buckling design is to be carried out.

In column I, three options are available for defining the equivalent uniform moment factor  $m_{LT}$ . The default value is 1.0. The factor can also be determined by the program according to table 18 [1] or entered manually.

Column J enables you to modify the lateral-torsional buckling coefficient  $K_{LT}$  which has an influence on the calculation of the lateral-torsional buckling length. The value of  $K_{LT}$  is preset to 1.0.

If the lateral-torsional buckling coefficient is changed, the respective lateral-torsional buckling length  $KL_{LT}$  is modified automatically. The values in column K depend on the settings in table 1.4 Lateral Intermediate Supports. It is also possible to enter values of  $KL_{LT}$  manually.

#### Comment

In the last column the user can enter remarks for every member, e.g. to explain more closely the specific lengths of a member.

The check box *Set Inputs for Members No.* is located beneath the tree-structure lower table. If you tick this box, the data entered <u>consequently</u> will become valid for specific resp. *All* members. You can select the members graphically by using the function [Pick] or enter their numbers manually. This option is useful when you want to assign the same boundary conditions to several members. Please notice that this function must be activated prior to data entering. If you define the data and choose this option later, the data is not re-assigned.

### 2.6 Effective Lengths - Sets of Members

The input table 1.6 controls the effective lengths for sets of members. It is only available if one or more sets of members have been selected in table 1.1 *General Data*.

A1 - Steel Design according tc 💙	1.0 LII		. · · · · · · · · · · · · · · · · · · ·	Sets of M								
nput Data	<u> </u>	A	B	C	D	E	F	G	н			J
– General Data	Set No.	Buckling Possible	Possible	about Maj		Possible	g about Mind Kz		Possible	Buckling		omment
Materials	2	FUSSIBLE	FUSSIBLE	K <sub>y</sub> 1.000	KL <sub>y</sub> [m] 6.000	FUSSIBLE	Nz 1.000	KL <sub>z</sub> [m] 3.000	FUSSIDIE	т.т.(-) 1.000		Jinineni
- Cross-sections	2			1.000	6.000		1.000	3.000		1.000		
<ul> <li>Lateral Intermediate Supports</li> <li>Effective Lengths - Members</li> </ul>												
<ul> <li>Effective Lengths - Members</li> <li>Effective Lengths - Sets of Me</li> </ul>												
<ul> <li>Nodal Supports</li> </ul>												
Set of Members No. 2 - Se	t											
Member Releases												
Set of Members No. 2 - Se	t											<b>I</b>
- Serviceability Data												
	Catting	a fan Sat	-f.)(	pers No.	2					IPE 450 (Br	ritish Steel)	
		<u>s for set</u> Members	or menn	Ders No.	2	[C	of Members			II E 400 (DI	. 190.0	
		ss-section					OF Members				190.0	+
	Lengt				1	1.5	6.000				+	2
		ina Possible			-		×				41	
	🖃 Buckl	ing about A:	kis y Possil	ole			×					
	- Effe	ective Leng	th Factor		Ky		1.000	)				
		ective Lengl			KLy		6.000	) m		460.0	i	·
		ing about A:		ole			×				9.4	
		ective Leng			Kz		1.000				0.4	-
		ective Leng			KLz		3.000					
		al-torsional B vivalent Unit					1.000				-	
	Comm		IOTH MOME	shi nactor	MLT		1.000	J			z	
	Comm	ICI IL										ín
	Set In	nputs for to !	Sets No.:					r an	🗹 All	0		🚔 🚼 🖸



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3



This table is very similar to the previous table 1.5. With regard to the effective lengths for buckling about the major and minor axes of the cross-sections, it is identical to table 1.5.

There are differences, however, as far as the parameters for torsional and lateral-torsional buckling are concerned. These are defined by means of specific boundary conditions in table 1.8 (see chapter 2.8).

### 2.7 Nodal Supports

The stability design of sets of members is based on the loads and the boundary conditions of the selected sets of members. The value of the multiplier  $\alpha_{cr}$  has to be determined for the entire set of members in order to obtain the critical stress  $p_E$  which is necessary for the design. The calculation of  $\alpha_{cr}$ , the bifurcation factor, also depends on the settings in the *Details* dialog box (see chapter 3.1, page 29).

To determine  $\alpha_{cr}$ , a planar member structure with four degrees of freedom per node is created. The specific support conditions are defined in table 1.7. This table is only available if you have selected one or more sets of member in table 1.1 *General Data*.

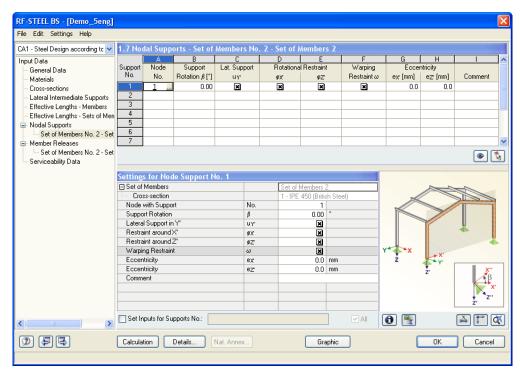


Figure 2.20: Table 1.7 Nodal Supports



5

To define the nodal supports, the orientation of the axes within a set of members is important. The program internally checks the location of the relevant nodes and then determines the axis systems of the nodal supports that are defined in table 1.7 (see figure 2.21 to figure 2.24).



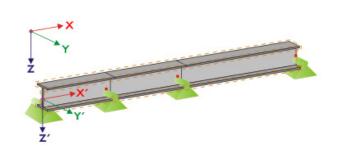


Figure 2.21: Auxiliary coordinate system for nodal supports - straight set of members

If all members within the set of members lie on a straight line, the local coordinate system of the first member within this set is applied for the entire set of members.

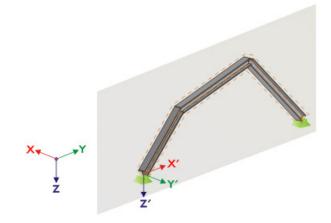


Figure 2.22: Auxiliary coordinate system for nodal supports - set of members in vertical plane

Even if the members within a set do not lie on a straight line, they still must lie in a plane. We can see a vertical plane in figure 2.22. In this case, the axis X' is horizontal and in the plane direction. The axis Y' is also horizontal, but perpendicular to the axis X'. The axis Z' points vertically downwards.

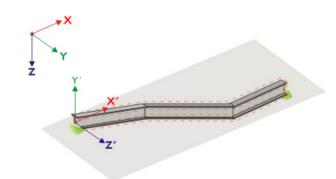


Figure 2.23: Auxiliary coordinate system for nodal supports - set of members in horizontal plane

If the members are located in a horizontal plane, the axis X' is parallel with the axis X of the global coordinate system. The axis Y' then points in the opposite direction of the global axis Z. The axis Z' is parallel with the axis Y of the global coordinate system.



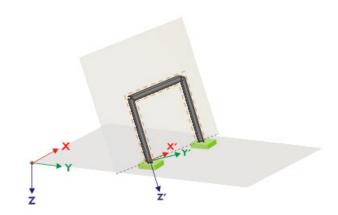


Figure 2.24: Auxiliary coordinate system for nodal supports - set of members in inclined plane

Figure 2.24 shows the most general case. The members within a set of members do not lie on a straight line but are located in one oblique plane. The orientation of the axis X' is then determined by the intersection between the oblique and the horizontal plane. The axis Y' is perpendicular to the axis X' and is also perpendicular to the oblique plane. The axis Z' is perpendicular to the axes X' and Y'.

### 2.8 Member Releases

This table is only available if one or more sets of members have been selected in table 1.1 *General Data*. If any member in a given set is not able to transfer internal forces corresponding to the degrees of freedom restricted in table 1.7, then nodal releases can be inserted to a set of members in table 1.8. There is also the possibility to exactly define on which side the release is to act or to place a release at both sides.

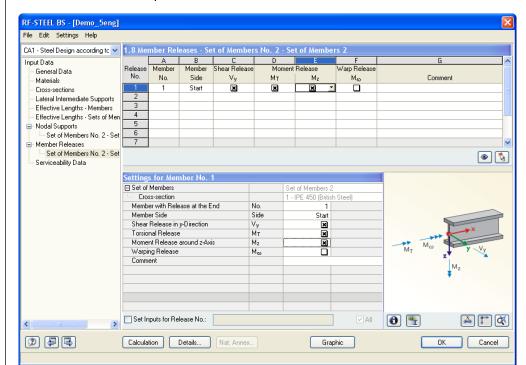


Figure 2.25: Table 1.8 Member Releases



### 2.9 Serviceability Data

The final input table includes different possibilities for the serviceability design. It is only displayed if the serviceability limit state design has been enabled in table 1.1 *General Data* (see figure 2.3, page 10).

CA1 - Steel Design according to 🔽	1.9 Sei	viceability Data	1						
Input Data		Α	В	С	D	E	F	G	Н
- General Data			Set of Members		ce Length	Direc-	Camber		
Materials	Nr.	Reference to	No.	Manually	L [m]	tion	w <sub>o,z</sub> [mm]	Beam Type	Comment
- Cross-sections	1	Member	1	×	6.000	у, z	0.0	Cantilever Start Free	
- Lateral Intermediate Supports	2	Set of Members	2	×	6.000	у, z	0.0	Beam	
Effective Lengths - Members	3	Member	11		6.000	у, z	0.0	Cantilever End Free	
Effective Lengths - Sets of Men	4	Member	13		3.011	У, Z	0.0	Beam	
- Nodal Supports	5	Member	91		5.000	у, z	0.0	Beam	
Set of Members No. 2 - Set	6	Member	92		5.000	у, z	0.0	Cantilever Start Free	
- Member Releases	7	Member	124		7.810	у, z	0.0	Beam	
Set of Members No. 2 - Set	8	Member	136		8.023	у, z	0.0	Beam	
Serviceability Data	9								
	10								
	11								
	12								
	13								
	14								
	15								
	16								
	17								
	18								
	19								
	20								
	21								
	22								
	23								
	24								
	25								
									()

Figure 2.26: Table 1.9 Serviceability Data

In column A, you decide whether you want to apply the deformation to single members, lists of members or sets of members.

....

In table column B, you enter the numbers of the members or sets of members that you want to design. You can also use the [Pick] function to select them graphically in the RFEM work window. The respective *Reference Length L* will be entered automatically in column D. In this column, the lengths of the member, sets of members or member lists are preset. If required, you can adjust those values after having ticked the *Manually* check box in column C.

Table column E defines the governing *Direction* for the deformation analysis. If necessary, a *Camber*  $\Delta_{camb}$  can be taken into account in column F.

The *Beam Type* (beam or cantilever) is very important to correctly apply the limit deformations. It can be entered in column G.

Details...

The settings shown in the *Serviceability* tab of the *Details* dialog box determine whether the deformations are related to the undeformed initial structure or to the shifted ends of members or sets of members (see chapter 3.1, page 29).



# 3. Calculation

### 3.1 Details

Calculation

<u>D</u>etails...

A particular design is carried out with the internal forces calculated in the RFEM program. Before the [Calculation], you should check the detailed setting for the design. Open the appropriate dialog box from every input or output table by clicking the [Details] button.

The Details dialog box consists of four tabs: Ultimate Limit State, Stability, Serviceability and Other.

### **Ultimate Limit State**

#### Options

RF-STEEL BS carries out a plastic design for cross-sections of classes 1 or 2. If needed, the *Elastic design* can be activated for those cross-section classes in the *Ultimate Limit State* tab.

### Stability

Details	
Ultimate Limit State Stability Serviceability Other	
<ul> <li>Stability Analysis</li> <li>✓ Check Stability</li> <li>Determination of Elastic Critical Moment for LTB</li> <li>Point of Load Application:</li> <li>On Cross-section Edge Directed to Shear Center (e.g. Top Flange, Destabilizing Effect)</li> <li>In Shear Center (Normal Effect)</li> <li>On Cross-section Edge Directed from Shear Center (e.g. Bottom Flange, Normal Effect)</li> </ul>	Structure Type         Sway y - y (my 2 0.85)         Sway z - z (m <sub>2</sub> 2 0.85)         Limit Load for Special Cases         Do not Take Small Moments into Account and Allow Stability Design according to Annex C (Axial Compression without Bending) if:         Bending       My / Moy ≤       0.010 $\diamondsuit$ Mz / Moz ≤       0.010 $\diamondsuit$ Mz / Moz ≤       0.010 $\diamondsuit$ Do not Take Small Compression Forces into Account and Allow Stability Design according to 4.3.6 (Bending without Compression) if:         Compression       Fo / Po ≤       0.010 $\diamondsuit$ Allow Futher Design if Shear Stresses due to Torsion does not Exceed Limit:       Torsion $\tau_t / p_v \leq$
	OK Cancel

Figure 3.1: Details dialog box, tab Stability

#### Stability Analysis

In this section you can decide whether the stability analysis is to be carried out in general. If the check is disabled here, the input tables 1.4 to 1.8 will not be active.



#### **Determination of Elastic Critical Moment for LTB**

Usually, loads act on members. Then their application point has to be specified because this can have stabilizing or destabilizing effects, subject to the eccentricity. The *Point of Applied Load* can be set globally for all loads.

The elastic critical stress  $p_E$  is calculated automatically for sets of members.

#### **Structure Type**

The structure type can be either *Non-sway* or *Sway*, which affects the calculation of  $m_y$  and  $m_z$ . For a sway-type structure, the values of  $m_y$  and  $m_z$  are assumed as 0.85.

#### Limit Load for Special Cases

It is possible to neglect small stresses due to bending compressive forces and torsion and, thus, allow a simplified design which eliminates negligible internal forces. In this dialog section, the limits of these internal forces or stresses can be entered. Those are defined as the ratios between existing internal forces or stresses and the corresponding resistances of each cross-section.

If one of those limits is exceeded, a comment will be given in the results table. There will be no stability design. Nevertheless, the design of the cross-section itself is carried out. Please not that those limit values are <u>not</u> part of the *British Standard*. If you change the limits, it will be in your own area of responsibility.

### Serviceability

#### Serviceability (Deflections)

In this section, it is possible to check or change the allowable deflections for the serviceability limit state design. The default values are L/360 for beams and L/180 for cantilevers.

The two selection fields below control whether the *Deformation* is to be related to the undeformed model or to an imaginary connecting line between the shifted start and end nodes of the member resp. set of members within the deformed structure.

#### Other



#### **Cross-section Optimization**

Cross-sections can be optimized if the *Optimize* option is chosen in table 1.3 *Cross-Sections*. (see figure 2.10, page 16). The dialog box *Details* enables you to set the maximum allowable design ratio as a limit for the optimization process.

#### **Check of Member Slendernesses**

It is possible to set user-defined slenderness ratios *KL/r* for members with tension resp. compression or flexure. These maximum values are compared with the actual member slendernesses in table 3.3 which is available after the calculation (see chapter 4.8).

#### **Display Results Tables**

In this section, the results tables can be specified which are to be displayed, inclusive of a parts list. The results tables are described individually in chapter 4.



### 3.2 Start Calculation

In all input tables of RF-STEEL BS, you can start the design via the [Calculation] button.

At first, RF-STEEL BS searches for the results of the selected load cases, load groups and combinations. If they are not found, the calculation of the governing internal forces in RFEM is started. The calculation parameters of RFEM are used for this analysis.

If cross-sections are to be optimized (see chapter 7.2, page 53), the required sections are calculated and relevant types of design are carried out.

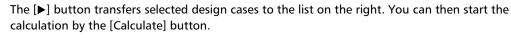
The RF-STEEL BS design can be also started from the RFEM interface. All design cases of the add-on modules are displayed in the *To Calculate* dialog box, similarly to load cases or load groups. Open this dialog box in RFEM via the main menu

Calculate  $\rightarrow$  To Calculate...

To Calculate								×
Not Calculated Program / Mod RFEM RF	N₀. LC1 LC2 LC3 LC4 LC5 LC6 LC7 LC8 LC9 LC1 LG2 LG3 LG4 LG5 LG6 LG6 LG6 LG7 LG8 LG9 LG11	Description           Dead Load           Snow Load           Wind v +X           Wind at peak v +Y           Wind at peak v -Y           Wind at peak v -Y           Wind positive           Live Load           Imperfections v +Y           1.35*LC1 + 1.5*LC2 + 1.35*LC           1.35*LC1 + 1.5*LC2 + LC8           1.35*LC1 + 1.5*LC2 + LC8           1.35*LC1 + 1.5*LC4 + LC10           1.35*LC1 + 1.5*LC4 + LC10		<b>×</b>	Selected for Calcula Program / Mod RF-STEEL BS	tion No. CA1	Description Steel Design according to BS	
RFEM RFEM	LG12 LG13	LC1 + LC2 + LC8 LC1 + LC3 + LC8	~					~
Show Additional	Modules							
9							Calculate Cance	:

Figure 3.2: To Calculate dialog box

If the design cases of RF-STEEL BS are missing in the list *Not Calculated*, it is necessary to tick the check box *Show Additional Modules*.



The calculation of a specific RF-STEEL BS design case can also be directly started from the toolbar. Set the required design case in the list and then click on the [Results on/off] button.

<u>A</u> dditional Modules	<u>W</u> indow	Help				
RF-STEEL BS CA1 - S	teel Desig <mark></mark>	< ⊲	> 3	🛓 🌊	x.xx	<b>5</b>
👹 💥 😰 🏚	<b>\$</b> 12	°ð 💠	<u> </u>		sults on/off	1

Figure 3.3: Direct calculation of RF-STEEL BS design case in RFEM



Calculation



A dialog box appears in which you can watch the progress of the design.

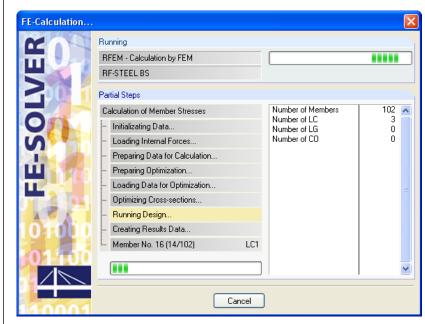


Figure 3.4: Calculation in RF-STEEL BS

0K



# 4. Results

Immediately after the design, table 2.1 *Design by Load Case* is displayed. The upper part of this table gives a summary of all designs for every load case, load group and combination. The lower part includes all details of the material properties, design internal forces and design data of the load case which is selected in the upper part of the table.

The results tables 2.1 to 2.5 contain the detailed design summaries according to different selection criteria. Tables 3.1 and 3.2 include the governing internal forces. In table 3.3, the member slendernesses are compared with the maximum values as set in the *Details* dialog box. The parts lists are displayed in the last two tables 4.1 and 4.2.

The results tables are accessible from the navigator in RF-STEEL BS. You can also switch among the tables via the buttons as seen to the left or the functional keys [F2] and [F3].

The [OK] button saves the results. The add-on module RF-STEEL BS is closed, and you return to the work window of RFEM.

In this chapter, all results tables are described in the given order. The following chapter 5 *Evaluation of Results* is devoted to the evaluation and checking of results.

### 4.1 Design by Load Case

'A1 - Steel Design according tc 🚩	2.1 Des	sign by Load Case						
nput Data		A	В	С	D	Ε	F	G
General Data	Load		Member	Location	Design			
Materials	Case	Description	No.	x [m]	Ratio		Design according to Formula	D
Cross-sections		Ultimate Limit State Desig	jn					
Lateral Intermediate Supports	LC1	Dead Load	21	0.000	0.77	≤1	351) Stability Analysis - Buckling about z-Axis and Ben	
Effective Lengths - Members	LC2	Snow Load	21	0.000	1.10	>1	351) Stability Analysis - Buckling about z-Axis and Ben	cU
Effective Lengths - Sets of Men	LC3	Wind v +X	11	0.857	0.18	≤1	322) Lateral Torsional Buckling according to 4.3 and E	3. UI
- Nodal Supports								
Set of Members No. 2 - Set		Serviceability Limit State	Design					
Member Beleases	LC1	Dead Load	91	2.500	0.23	≤1	401) Serviceability - Deflection in z-Direction for Beam	
Set of Members No. 2 - Set	LC2	Snow Load	13	1.506	0.29	≤1	401) Serviceability - Deflection in z-Direction for Beam	
Serviceability Data								
Results							8 92 8 5 2 3	10
Design by Load Case				Max	1.10	21	8 788 558	
Design by Cross-section								
- Design by Set of Members	Details	- Member 21 - x: 0.	000 m - LC	1			1 - IPE 400 (British Steel)	
Design by Member	Mater	ial Values - Steel S 355					180.0	
Design by x-Location	Cross-	-section Values - IPE 400	(British Steel)					
Governing Internal Forces by M		n Internal Forces						
Governing Internal Forces by S	E Cross	-section Classification - Cla	ss 3				2 P	
Member Slendernesses	🖯 Desig	n Ratio						
Parts List by Member	— Axi	al Compression	Fo	79.948	kN			Þ
Parts List by Set of Members	De:	sign Strength	Pv	35.50	kN/cm <sup>2</sup>			У
	Gro	oss Area	Ag	8450.0	mm <sup>2</sup>			
	— Mo	dulus of Elasticity	E	21000.00	kN/cm <sup>2</sup>			
	- No	minal Effective Length	KLz	6.000	m			
	- Ra	dius of Gyration	ſz	39.5	mm		z	
	Sle	nderness	λz	151.922			4.7.2	[m
				45.000			C.2	
	— Lim	niting Slenderness	λο	15.282			Table 23 😈 🕄	*)[0

Figure 4.1: Table 2.1 Design by Load Case

#### Description

In this column, the descriptions of the load cases, load groups and combinations are displayed that are decisive for every relevant type of design.

#### Member No.

The number of the member with the highest design ratio is stated for every designed load case, load group or combination.



### Location x

The location x on the member where the maximum stress ratio occurs is displayed in this column. The following locations x on the member are taken into account:

- Start and end nodes
- Internal nodes according to potential user-defined member division
- Member division according to specification for member results (*Options* tab of RFEM dialog box *Calculation Parameters*)
- Extreme values of internal forces

### **Design Ratio**

For every design type and for every load case, load group or combination, the design quotients according to the standard are displayed in this column.

The colored scales represent the design ratios due to the individual load cases.

### Design according to Formula

In this column, the equations that were followed in the design are listed.

### DS

The final column gives information on the respective design-relevant *Design Situation: ULS* (ultimate limit state) or one of the three design situations for serviceability (*CH*, *FR*, *QP*) according to the specification in table 1.1 *General Data* (see figure 2.3, page 10).

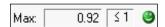
### 4.2 Design by Cross-Section

le Edit Settings Help														
A1 - Steel Design according tc 🗸	2.2 De	sign by	Cross-sect	tion										
nput Data		A	В	С	D	E					F			
General Data		Member		Load	Design	1								
- Materials	No.	Nr.	x [m]	Case	Ratio				-		ding to Forr	nula		
Cross-sections		13	0.000	LC1	0.00				o or Very Sm					
- Lateral Intermediate Supports		13	1.506	LC2	0.29	≤1 4	01) Service	ability - De	eflection in z	-Dire	ction for Be	am		
Effective Lengths - Members														_
Effective Lengths - Sets of Men	3	IPE 330	l (British Steel											
Nodal Supports		41	0.000	LC2	0.04				eck - Compre					
Set of Members No. 2 - Set		13	0.000	LC3	0.10								r acc. to 4.2.5	
- Member Releases		23	0.000	LC2	0.08								e Web acc. to	24
Set of Members No. 2 - Set		3	0.000	LC1	0.00				eck - Shear B					
Serviceability Data		23	0.000	LC2	0.60	≤1 [1	81) Cross-se	ection Che	eck - Bendin	ig ab	out y Axis,	Shear and A	kial Force acc.	<u>.</u>
esults				Max:	1 10	>1 6			9		2 9	E V	1 😂 💿	1
Design by Load Case				Max.	1.10		,							1
Design by Cross-section	_									-				
Design by Set of Members			ber 23 - x:		m - LC2						3 - 2: IPE 3		teel) - IPE 400	) (
Design by Member			: - Steel S 355							^		+ 160.0	+	
Design by x-Location			alues - IPE	330 (Briti:	sh Steel)									
Governing Internal Forces by M		an Internal										2	-	
- Governing Internal Forces by S			Classification -	Class 1								=		
- Member Slendernesses	🖂 Desigi										9			
- Parts List by Member		ial Compre		Fo		-31.780					330.0		·*	,
- Parts List by Set of Members		nding Mon		M		166.930						7.5	5	
-			on Modulus	S	y 8	304000.0								
		esign Stren		P:	y .		kN/cm <sup>2</sup>					_ easter	-	
		ear Design		办		0.08		≤ 0.6				÷		
		oment Capi				285.420			4.2.5.2			z		
			Resistance	P	° 2	2222.300			4.7.4					I
	C	moreeeion	Design Ratio	0 No	1	0.01		≤ 1			0			1
		ndina Desi			πy	0.58								

Figure 4.2: Table 2.2 Design by Cross-Section

In this table, the maximum design ratios are displayed for all designed members and all designed load cases, groups and combinations. The results are listed by cross-sections.

For tapered members, both cross-section descriptions are shown in the line next to the cross-section number.





### 4.3 Design by Set of Members

:A1 - Steel Design according to 💌	2.3 De	sign by	Set of Mer	nbers								
nput Data		A	В	С	D	E				F		
- General Data	Set No.	Member	Location	Load	Design							
- Materials	INO.	Nr.	x [m]	Case	Ratio			~		ding to Forn		
- Cross-sections		1	0.000	LC2	0.02						Parallel to the Web	acc. to 4
- Lateral Intermediate Supports		1	0.000	LC1	0.00			tion Check - Shea				
Effective Lengths - Members		1	6.000	LC2	0.19						Shear and Axial For	
Effective Lengths - Sets of Men		1	3.000	LC3	0.05						nd B.2 (I, H and Ch	
Nodal Supports		1	0.000	LC1	0.13						ut y and z Axis acc.	
Set of Members No. 2 - Set		1	3.000	LC2	0.26						Bending about y an	
🖃 Member Releases		1	4.286	LC1	0.09						and Bending about	
Set of Members No. 2 - Set		1	3.429	LC2 LC1	0.76			nalysis - Buckling pility - No or Verv S			and Bending about	y and z-A>
- Serviceability Data			0.000	LUI	0.00	214	400) Servicead	niity - No or Very 5	maii D	eriection		
Results				Max	1.10	>1 🧯	9	4	1	2 8	🖺 🍢 🔮	][@]['
Design by Load Case												
Design by Cross-section	Dotaile	Momb	er 1 - x: 3	2 4 2 0 -	n 1C2					1 - IPE 400	) (British Steel)	
Design by Set of Members			- Steel S 355		II · LCZ				~	1 - 11 - 400	180.0	
Design by Member			alues - IPE		ala Cha all						+ 100.0	
<ul> <li>Design by x-Location</li> </ul>		n Internal		400 (BIIU	snioteelj				- 1			
<ul> <li>Governing Internal Forces by M</li> </ul>			lassification -	Class 1							8	
- Governing Internal Forces by S			iassincation -	Class I					- =		-1	
Member Slendernesses		al Compre	eeion	F		23.438	R IN		-	0.00		
Parts List by Member		sian Stren		P	•		kN/cm <sup>2</sup>			4		Γy .
Parts List by Set of Members		sign Stren Iss Area	3	A			) mm <sup>2</sup>		-9		8.0	
		dulus of E	lasticity	F			) kN/cm <sup>2</sup>		- 1			
			Resistance			2999.750		474 an	d		-	
			Design Ratio		nz s	0.01		4.8.3.3	-		z	
		ximum Ma			1LT,y,ma		S kNm		-			ſm
					E	3.000		4.3.5	- 1	0		
								4.3.6.7				

Figure 4.3: Table 2.3 Design by Set of Members

This table is displayed if at least one set of members was selected for design. The maximum design ratios are listed according to sets of members. The number of the member with the highest design ratio within each set of members is shown in the *Member Nr.* column.

### 4.4 Design by Member

CA1 - Steel Design according to 🔽	2.4 Des	ign by Me	mber											
nput Data		A	В	С	D					Ε				
- General Data	Member	Location	Load	Design										
- Materials	No.	x [m]	Case	Ratio				De	esign accor	ding I	to Formula	1		
Cross-sections	1			IPE 400 (Britis										
- Lateral Intermediate Supports		0.000	LC1	0.02		102) Cross-								
- Effective Lengths - Members		5.143	LC3	0.03								Shear acc. to		
Effective Lengths - Sets of Men		0.000	LC2	0.02								to the Web	acc. to 4.2.3	3
Nodal Supports		0.000	LC1	0.00		126) Cross-								
Set of Members No. 2 - Set		6.000	LC2	0.19								nd Axial Forc		
🗐 Member Releases		3.000	LC3	0.05								, H and Cha		sectio
- Set of Members No. 2 - Set		0.000	LC1	0.13								z-Axis acc. I		
- Serviceability Data		3.000	LC2	0.26	≤ 1	351) Stabili	ty Analysis	- Buckling	about z-Ax	is an	d Bending	about y and	J z-Axis with	Latera
Results			Max:	1.10	>1	0			۹	1	2.9	EV	J 🖭 🖉	<u></u>
<ul> <li>Design by Load Case</li> </ul>			in an			·								
<ul> <li>Design by Cross-section</li> </ul>	<b>D</b>				~ ~						4 105 40	0.00.00.00		
<ul> <li>Design by Set of Members</li> </ul>				.000 m - L	C2					_	1 - IPE 40	0 (British St	· · ·	
Design by Member		al Values - St								<u>^</u>		180.1	+	
Design by x-Location				400 (British Ste	eelj									
- Governing Internal Forces by M		n Internal For										8		
- Governing Internal Forces by Si		section Class	ification -	Class 1								≌		
Member Slendernesses	🗆 Design				_						0.04			
<ul> <li>Parts List by Member</li> </ul>		al Compressio		Fo	_	-23.438					9	i 1		*y
Parts List by Set of Members		iding Momen		My	_	83.466							3.6	
		stic Section M	todulus	Sy	_	1307000.0								
		ign Strength		Ру	_		kN/cm <sup>2</sup>							
		ear Design Ra		ψvz		0.02		≤ 0.6	1050			÷		
		ment Capacity		Moy		463.985			4.2.5.2			z		
		npression Re		Po		2999.750	ĸN		4.7.4					[m
		npression De:		1.5	_	0.01		≤ 1			0			
	- Ber	nding Design	Hatio	Ψmy		0.18			1	Y	9			

Figure 4.4: Table 2.4 Design by Member



In this table, the maximum design ratios are arranged according to member numbers.

The description of the individual columns can be found in chapter 4.1 on page 33.

### 4.5 Design by x-Location

🏹 - Steel Design according to 🔽	2.5 Des	ign by x-L							
nput Data		A	В	С	D		E		
- General Data	Member No.	Location	Load	Design	1				
- Materials		x [m]	Case	Ratio			Design according	to Formula	
- Cross-sections	1			IPE 400 (Brit					
<ul> <li>Lateral Intermediate Supports</li> </ul>		0.000	LC1	0.02		102) Cross-section Check - C			
<ul> <li>Effective Lengths - Members</li> </ul>		0.000	LC2	0.02		121) Cross-section Check - S			o the Web acc. to 4.2.3
- Effective Lengths - Sets of Men		0.000	LC1	0.00		126) Cross-section Check - S			
Nodal Supports		0.000	LC1	0.13		341) Stability Analysis - Buckl			
- Set of Members No. 2 - Set		0.000	LC2	0.14		351) Stability Analysis - Buckl			
Member Releases		0.000	LC1	0.04		371) Stability Analysis - Buckl			
- Set of Members No. 2 - Set		0.000	LC2	0.72		372) Stability Analysis - Buckl			ing about y and z-Axis acc. I
Serviceability Data		0.000	LC1	0.00	≤1	400) Serviceability - No or Ve	ry Small Deflection		
esults			Max	1.10	>1	0	9	2 8	E 🖪 😤 💿
<ul> <li>Design by Load Case</li> </ul>			T-T-GIT.			-			
<ul> <li>Design by Cross-section</li> </ul>	D 4 11		4 0	000	64			4 105 400	(British Steel)
<ul> <li>Design by Set of Members</li> </ul>				).000 m - l	LCT			1 - IPE 400	
<ul> <li>Design by Member</li> </ul>		al Values - SI					^		+ 180.0 + +
<ul> <li>Design by x-Location</li> </ul>				400 (British SI	teelj				
<ul> <li>Governing Internal Forces by M</li> </ul>		n Internal For							8
- Governing Internal Forces by S			sification -	No Compress	sion				21
<ul> <li>Member Slendernesses</li> </ul>	🗆 Desigi			-				0.00	
Parts List by Member		al Compressio		Fo	_	71.719 kN		6	y
Parts List by Set of Members		ign Strength		Py		35.50 kN/cm <sup>2</sup>			8.6
		ss Area		Ag		8450.0 mm <sup>2</sup>			
		dulus of Elast		E		21000.00 kN/cm <sup>2</sup>		-	_ colore
		ninal Effectiv		KLz		3.000 m			÷
		dius of Gyratio	on	ſz		39.5 mm	170		z
		nderness		λz		75.961	4.7.2		[r
		iting Slendern ut Curve	ness	λ0 SC2		15.282 b	C.2 Table 23	0	[Ă] [ᢪ]

Figure 4.5: Table 2.5 Design by x-Location

This results table lists the maximum values of every member at the following locations x according to the division points of RFEM:

- Start and end nodes
- Internal nodes according to potential user-defined member division
- Member division according to specification for member results (*Options* tab of RFEM dialog box *Calculation Parameters*)
- Extreme values of internal forces



# 4.6 Governing Internal Forces by Member

In this table, the governing internal forces are shown, i.e. those internal forces that lead to the maximum design ratios.

A1 - Steel Design according tc 💌	3.1 Go	/erning li	nternal	Forces by	/ Membei					
nput Data		A	B	C	D	E	F	G	Н	I
- General Data	Member No	Location	Load		orces [kN]			ments [kNm		
- Materials		x [m]	Case	N	Vy	Vz	Мт	My	Mz	Design according to Formula
- Cross-sections	1			IPE 400 (B	,					
- Lateral Intermediate Supports		0.000	LC1	- <b>71</b> ,719	0.000	-1 <mark>0</mark> .852	0,001	0.000		102) Cross-section Check - Compression
- Effective Lengths - Members		5.143	LC3	1,170	0.000	0.327	0,000	14.907		111) Cross-section Check - Bending at
- Effective Lengths - Sets of Men		0.000	LC2	-2 <mark>3</mark> ,438	0.000	-13.911	0,000	0.000		121) Cross-section Check - Shear Cap
Nodal Supports		0.000	LC1	- <b>71</b> ,719	0.000	-1 <mark>0</mark> .852	0,001	0.000		126) Cross-section Check - Shear Buck
Set of Members No. 2 - Set		6.000	LC2	-2 <mark>3</mark> ,438	0.000	-13.911	0,000	- <mark>83</mark> .466	0.000	
<ul> <li>Member Releases</li> </ul>		3.000	LC3	1,170	0.000	2.470	0,000	11.910	0.000	
- Set of Members No. 2 - Set		0.000	LC1	- <mark>71</mark> .719	0.000	-1 <mark>0</mark> .852	0,001	0.000	0.000	
- Serviceability Data		3.000	LC2	-2 <mark>3</mark> ,438	0.000	-13.911	0,000	- <b>41</b> .733		351) Stability Analysis - Buckling about
esults		4.286	LC1	-3 <mark>3</mark> 680	0.000	-10.852	0,001	-46.507	-0.001	
- Design by Load Case		3.429	LC2	-2 <mark>3</mark> ,438	0.000	-13.911	0,000	-47.695	0.000	
<ul> <li>Design by Cross-section</li> </ul>		0.000	LC1	- <b>71</b> ,719	0.000	-1 <mark>0</mark> .852	0,001	0.000	0.000	
<ul> <li>Design by Set of Members</li> </ul>		3.429	LC2	-2 <mark>3</mark> ,438	0.000	-13.911	0,000	-47.695		401) Serviceability - Deflection in z-Dire
- Design by Member		3.429	LC2	-2 <b>3</b> ,438	0.000	-13.911	0,000	47.695	0.000	403) Serviceability - Deflection in z-Dire
<ul> <li>Design by x-Location</li> </ul>										
- Governing Internal Forces by M	2			IPE 400 (B	ritish Steel)					
- Governing Internal Forces by S		0.000	LC1	- <mark>71</mark> ,719	0.000	10.852	0,000	0.000	0.000	
Member Slendernesses		6.000	LC3	-1,170	0.000	0.530	0,000	14.429	0.000	
Parts List by Member		0.000	LC2	-2 <b>3</b> ,438	0.000	13.911	0,000	0.000		121) Cross-section Check - Shear Cap
Parts List by Set of Members		0.000	LC1	- <mark>71</mark> .719	0.000	10.852	0,000	0.000		126) Cross-section Check - Shear Buc
		6.000	LC2	-2 <mark>3</mark> ,438	0.000	13,911	0,000	83.466		181) Cross-section Check - Bending at
		0.000	LC3	-1,170	0.000	4.280	0,000	0.000	0.000	
		0.000	LC1	- <mark>71</mark> ,719	0.000	10.852	0,000	0.000	0.000	
		0.000	LC2	-2 <mark>3</mark> ,438	0.000	13.911	0,000	0.000	0.000	351) Stability Analysis - Buckling about
										<b></b>

Figure 4.6: Table 3.1 Governing Internal Forces by Member

#### Location x

For every member, the location x on the member with the maximum design ratio is shown.

#### Load Case

In this column, the numbers of the load cases, load groups or combination whose internal forces have the most unfavorable effects are displayed.

### Forces / Moments

The decisive axial and shear forces as well as the torsional and bending moments are listed for every member.

### **Design according to Formula**

The last column includes the relevant types of design and equations that were followed in the design.



# 4.7 Governing Internal Forces by Set of Members

'A1 - Steel Design according tc 🔽	3.2 Go	verning Ir	nternal	Forces by	/ Set of M	ember				
nput Data		A	В	С	D	E	F	G	Н	I
- General Data	Set No.	Location	Load		orces [kN]			oments [kNr		
- Materials		x [m]	Case	N	Vy	Vz	Мт	My	Mz	Design according to Formula
- Cross-sections	2			ember No. 1						
- Lateral Intermediate Supports		0.000	LC1	-71.719	0.000	-10.852	0.001	0.000		102) Cross-section Check - Compression
Effective Lengths - Members		5.143	LC3	1.170	0.000	0.327	0.000	14.907		111) Cross-section Check - Bending abo
<ul> <li>Effective Lengths - Sets of Men _</li> </ul>		0.000	LC2	-23.438	0.000	-13.911	0.000	0.000		121) Cross-section Check - Shear Capac
<ul> <li>Nodal Supports</li> </ul>		0.000	LC1	-71.719	0.000	-10.852	0.001	0.000		126) Cross-section Check - Shear Buckl
Set of Members No. 2 - Set .		6.000	LC2	-23.438	0.000	-13.911	0.000	-83.466		181) Cross-section Check - Bending abo 322) Lateral Torsional Buckling accordin
Member Releases		3.000	LC3 LC1	1.170	0.000	2.470 -10.852	0.000	11.910		322) Lateral Torsional Buckling according 341) Stability Analysis - Buckling and Be
Set of Members No. 2 - Set		0.000	LC1 LC2	-23.438	0.000	-10.852	0.001	-41.733		351) Stability Analysis - Buckling about z
Serviceability Data		4.286	LC2	-23.438	0.000	-10.852	0.000	-41.733		371) Stability Analysis - Buckling about 2
lesults		4.286	LC1 LC2	-33.680	0.000	-10.852	0.001	-46.507		371) Stability Analysis - Buckling about y 372) Stability Analysis - Buckling about y
Design by Load Case		0.000	LC2	-23.430	0.000	-10.852	0.000	-47.633		400) Serviceability - No or Very Small De
Design by Cross-section		3.429	LC2	-23.438	0.000	-13.911	0.001	-47.695		400) Serviceability - No of Very Small De 401) Serviceability - Deflection in z-Direc
- Design by Set of Members		3.423	LC2	-23.438	0.000	-13.911	0.000	-47.635		401) Serviceability - Deflection in 2-Direct
- Design by Member		3.423	LUZ	-23.430	0.000	13.311	0.000	-47.033	0.000	403) Serviceability - Denection In 2-Direct
Design by x-Location										
Governing Internal Forces by M										
<ul> <li>Governing Internal Forces by Semi Member Stendernesses</li> </ul>										
Parts List by Member										
Parts List by Set of Members										
										🖺 😂 💿 (*

Figure 4.7: Table 3.2 Governing Internal Forces by Set of Members

In this results table, the governing internal forces that lead to the maximum design ratios of every set of members are shown.

# 4.8 Member Slendernesses

🏹 - Steel Design according to 🔽	3.3 Mer	nber Slendernesses							
nput Data		A	В	С	D	E	F	G	Н
- General Data 	Member No.	Under Stress	Length L [m]	Ky	Major Axis y ry [mm]	KLy / ry	Kz	Minor Axis z rz [mm]	KLz / rz
Cross-sections	1	Compression/Flexure	6.000	1.000	165.4	36.265	0.500	39.5	75.961
Lateral Intermediate Supports	2	Compression/Flexure	6.000	1.000	165.4	36.265	1.000	39.5	151.922
Effective Lengths - Members	3	Compression/Flexure	3.011	1.000	137.1	21.961	0.333	35.5	28.292
Effective Lengths - Sets of Men	4	Compression/Flexure	3.262	1.000	165.4	19.719	1.000	39.5	82.607
Nodal Supports	5	Compression/Flexure	6.274	1.000	165.4	37.921	0.250	39.5	39.715
Set of Members No. 2 - Set	6	Compression/Flexure	6.274	1.000	165.4	37.921	1.000	39.5	158.860
Member Releases	7	Compression/Flexure	3.262	1.000	165.4	19.719	1.000	39.5	82.607
Set of Members No. 2 - Set	8	Compression/Flexure	3.011	1.000	137.1	21.961	1.000	35.5	84.876
Serviceability Data	11	Compression/Flexure	6.000	1.000	165.4	36.265	1.000	39.5	151.922
esults	12	Compression/Flexure	6.000	1.000	165.4	36.265	1.000	39.5	151.922
- Design by Load Case	13	Compression/Flexure	3.011	1.000	137.1	21.961	1.000	35.5	84.876
Design by Cross-section	14	Compression/Flexure	3.262	1.000	165.4	19.719	1.000	39.5	82.607
Design by Set of Members	15	Compression/Flexure	6.274	1.000	165.4	37.921	1.000	39.5	158.860
Design by Member	16	Compression/Flexure	6.274	1.000	165.4	37.921	1.000	39.5	158.860
Design by x-Location	17	Compression/Flexure	3.262	1.000	165.4	19.719	1.000	39.5	82.607
Governing Internal Forces by M	18	Compression/Flexure	3.011	1.000	137.1	21.961	1.000	35.5	84.876
Governing Internal Forces by S	21	Compression/Flexure	6.000	1.000	165.4	36.265	1.000	39.5	151.922
Member Slendernesses	22	Compression/Flexure	6.000	1.000	165.4	36.265	1.000	39.5	151.922
Parts List by Member	23	Compression/Flexure	3.011	1.000	137.1	21.961	1.000	35.5	84.876
Parts List by Set of Members	24	Compression/Flexure	3.262	1.000	165.4	19.719	1.000	39.5	82.607
	25	Compression/Flexure	6.274	1.000	165.4	37.921	1.000	39.5	158.860
	26	Compression/Flexure	6.274	1.000	165.4	37.921	1.000	39.5	158.860
					Members wi	th Compression	h / Flexure:		
					Max KLy/ry	r: 163.703	≤ 200	9	
					Max KLz / rz	172.823	≤ 200 🤅	•	50

Figure 4.8: Table 3.3 Member Slendernesses



In table 3.3, the effective slenderness ratios of all designed members are compared with the maximum values that were set in the *Details* dialog box (see chapter 3.1). These ratios are listed with respect to the major and minor principal axes. This table provides information on the maximum effective slenderness ratios only, it does not give any design results.

Members of the types "Tension" or "Cable" are excluded from this table.

# 4.9 Parts List by Member

Finally, the parts list of all cross-sections that are considered in the design case is displayed.

X41 - Steel Design according tc 🔽	4.1 Pa	rts List by Member								
nput Data	- ·	A	B	C	D	E	F	G	H	
General Data	Part No.		Number	Length	Tot Length			Unit Weight	Weight	Tot We
Materials	140.	Cross-section	Members	[m]	[m]	[m <sup>2</sup> ]	[m <sup>3</sup> ]	[kg/m]	[kg]	[t]
Cross-sections	1	1 - IPE 400 (British Steel)	6	6.00	36.00	52.80	0.30	66.33	397.99	2.
- Lateral Intermediate Supports	2	2 - IPE 400 (British Steel) 3 - IP	8	3.01	24.09	32.77	0.18	57.74	173.86	1.
- Effective Lengths - Members	3	2 - IPE 400 (British Steel)	8	3.26	26.10	38.28	0.22	66.33	216.41	1.
- Effective Lengths - Sets of Men	4	2 - IPE 400 (British Steel)	8	6.27	50.19	73.62	0.42		416.17	3.
Nodal Supports	5	1 - IPE 400 (British Steel)	4	3.00	12.00	17.60	0.10	66.33	199.00	0.
Set of Members No. 2 - Set	6	10 - UBP 203x203x54 (British Ste	3	3.00	9.00	10.79	0.06	53.93	161.79	0.
Member Releases	7	10 - UBP 203x203x54 (British Ste	2	3.55	7.09	8.50	0.05	53.93	191.23	0.
- Set of Members No. 2 - Set	8	10 - UBP 203x203x54 (British Ste	1	4.09	4.09	4.91	0.03	53.93	220.79	0.
Serviceability Data	9	15 - UBP 254x254x63 (British Ste	4	3.00	12.00	17.73	0.10	62.96	188.87	0.
Results	10	6 - UBP 254x254x71 (British Steel	3	3.00	9.00	13.37	0.08	70.96	212.89	0.
- Design by Load Case	11	6 - UBP 254x254x71 (British Steel	2	3.55	7.09	10.54	0.06	70.96	251.64	0.
Design by Cross-section	12	6 - UBP 254x254x71 (British Steel	1	4.09	4.09	6.08	0.04	70.96	290.53	0.
- Design by Set of Members	13	7 - UBP 203x203x45 (British Steel	4	6.27	25.10	29.80	0.14	44.90	281.71	1.
- Design by Member	14	9 - IPER 450 (British Steel)	8	6.25	50.00	80.47	0.61	94.99	593.66	4.
Design by x-Location	15	16 - IPE 360 (British Steel)	1	6.55	6.55	8.86	0.05	57.07	373.58	0.
Governing Internal Forces by M	16	6 - UBP 254x254x71 (British Steel	1	7.09	7.09	10.54	0.06	70.96	503.42	0.
Governing Internal Forces by S	17	6 - UBP 254x254x71 (British Steel	1	6.55	6.55	9.72	0.06	70.96	464.53	0.
Member Slendernesses	18	12 - QRO 80x5,0 (British Steel)	25	5.00	125.00	38.63	0.19	11.70	58.48	1.
Parts List by Member	19	13 - Circle 24	4	7.81	31.24	2.36	0.01	3.55	27.74	0.
Parts List by Set of Members	20	13 - Circle 24	8	8.02	64.18	4.84	0.03	3.55	28.49	0.
	Sum		102		516.46	472.20	2.79			21.
		1								٩

Figure 4.9: Table 4.1 Parts List by Member

Details...

This list contains only designed members by default. If all members of the structure are to be included, you can change the settings in the *Other* tab of the *Details* dialog box (see chapter 3.1). This dialog box is accessible via the [Details] button.

#### Part No.

The same part number is automatically assigned to identical members.

### **Cross-section**

In this column, the cross-section description is displayed.

#### Number of Members

The number of identical members is given for each part.

#### Length

This column displays the unit lengths of every single member.

### **Total Length**

This column represents the product of the values given in the two previous columns.



### Surface Area

The surface area which is related to the total length of the relevant part is calculated on the basis of the value  $A_{surf}$  of each cross-section. You can check on this value by clicking on the [Info about Current Cross-Section] button in tables 1.3 or 2.1 to 2.5.

### Volume

A

The volume of every part is calculated from the surface area and the total length.

### **Unit Weight**

The *Unit Weight* of the cross-section represents the weight per length of 1 m. For tapered cross-sections, the unit weight is calculated as the mean value of both cross-sections.

### Weight

The value in this column is calculated as the product of values in the columns C and G.

### **Total Weight**

The total weight of each part is displayed in the last column.

#### Sum

The sums of the values listed in columns B, D, E, F and I are given in the final row of the list. The cell *Total Weight* shows the total required mass of steel.

# 4.10 Parts List by Set of Members

CA1 - Steel Design according to 🔽	4.2 Pa	rts List by Set of Members								
Input Data General Data Materials Cross-sections Lateral Intermediale Supports Effective Lengths - Members Effective Lengths - Sets of Men Nodal Supports Set of Members No. 2 - Set Member Releases Set of Members No. 2 - Set Serviceability Data Results Design by Load Case Design by Cross-section Design by Member Design by Accoston Governing Internal Forces by M Governing Internal Forces by S Member Parts List by Member Parts List by Set of Members	Part No. Sum	A Description of Set of Members Set of Members 2	B Number Sets 1 1	C Length [m] 6.00	D Tot Length (m) 6.00 6.00	[m <sup>2</sup> ]	F [m <sup>3</sup> ] 0.05 0.05	G Uni Weight [kg/m] 66.33	H (kg) 397.99	L Tot Weig [t] 0.3
	Calcula	ition Details Nat. Ann	ex		Graphic			OK		💌 🐧

Figure 4.10: Table 4.2 Parts List by Set of Members

The last table in RF-STEEL BS is presented when at least one set of members was selected for the design. The advantage of this table is that a parts list is given for the various groups of elements (e.g. for a beam).

The table columns are described in chapter 4.9. If there are different cross-sections within the set of members, the mean values of surface area, volume and unit weight are listed.



# 5. Evaluation of Results

The design results can be evaluated in different ways. For this, the buttons in the results tables are very useful which are located below the upper tables.

:A1 - Steel Design according to 🗙	2.2 De	sign by	Cross-sec	tion								
nput Data		A	B	C	D	E				F		
- General Data	Section	Member		Load	Design	ן ו				r . F		
- Materials		Nr.	x [m]	Case	Ratio			U	esign accori	ding to Form	ula	
- Cross-sections	1		(British Steel		0.01	4 1 1 1		CI 1	<u> </u>		2.4	
<ul> <li>Lateral Intermediate Supports</li> </ul>		31	0.000	LC1	0.04		2) Cross-secti					
Effective Lengths - Members		11	5.143	LC3	0.06						r Low Shear acc. to 4.2	
<ul> <li>Effective Lengths - Sets of Men</li> </ul>		32	0.000	LC2	0.11						Parallel to the Web acc.	to 4
Nodal Supports		1	0.000	LC1 LC2	0.00		6) Cross-secti				4.4.5 hear and Axial Force a	
- Set of Members No. 2 - Set		21	6.000	LC2 LC3	0.38							
Member Releases		11	0.857	LC3	0.18						d B.2 (I, H and Channe t v and z-Axis acc. to 4.	
Set of Members No. 2 - Set		21 21	0.000	LC2	0.32						t y and z-Axis acc. to 4. ending about y and z-A	
Serviceability Data		21	0.000	LL2	1.10	21 35	r ji Stability Ah	alysis - Buc				XIS W
Results				Max:	1.10	>1 😁				2 8	🖺 🚮 😂 🍳	) [ (
Design by Load Case									0			
Design by Cross-section	Dotaile	Morel	ber 31 - x:	0.000	m 1.01					1 - IPE 400	(British Steel)	_
<ul> <li>Design by Set of Members</li> </ul>			- Steel S 355		III - LUT					1 - 1 - 400	180.0	
<ul> <li>Design by Member</li> </ul>			(alues - IPE		l. CuD						+ + + +	
Design by x-Location		n Internal		400 (Dhus	an Steelj					+	-	
- Governing Internal Forces by M			lassification -	No Com	veccion						13.5	
- Governing Internal Forces by S	E Desig		Jassincation -	NO COM	16221011							
Member Slendernesses		al Compre	recion		Fe	1137	IO kN			0.00		
Parts List by Member		ar compre ss Area	saalutt		Ag		.0 mm <sup>2</sup>			4		Y.
Parts List by Set of Members		sian Strer	ath		Pv		50 kN/cm <sup>2</sup>				8.6	
			Resistance		Po	2999.7			4.7.4			
		sian Ratio			ŋ	2000.1		≤1	4.7.4	+		
	00	sigiririadu	,		9	0.	.4	21	4.7.4		<b>.</b>	
											4	<b>1</b>
										_		[m
					1					8	X. 1	- 1
											→ ↓	

Figure 5.1: Buttons for evaluation of results

These buttons have the following functions:

Button	Name	Function
9	Design of Ultimate Limit State	Switch on/off the design results of the ultimate limit state
<b>?</b>	Design of Serviceability Limit State	Switch on/off the design results of the serviceabi- lity limit state
	Show Color Bars in Table	Switch on/off the color background in the results tables according to the reference scale
<b>7</b> ,1	Show Rows with Ratio > 1	Show only rows with stress ratios greater than 1 and, accordingly, failed design
	Show Result Diagrams of Current Member	Open the diagram <i>Result Diagram on Member</i> → chapter 5.2, page 46
۲	Jump to Graphics to Change View	Go to the RFEM work window in order to change the display settings
The second secon	Pick Member in Graphics and Go to This Member in Table	Click on a specific member in the RFEM window whose result values are to be displayed in the table

Table 5.1: Buttons in results tables 2.1 to 2.5



# 5.1 Results on RFEM Model

You can use the RFEM work window to evaluate the design results.

# RFEM background graphic and view mode

The RFEM graphics in the background can be useful if you want to check the location of a particular member in the model. The member that is selected in the RF-STEEL BS results table is also highlighted in the selection color in the RFEM background graphic. Additionally, an arrow marks the member location x which is stated in the active table row.

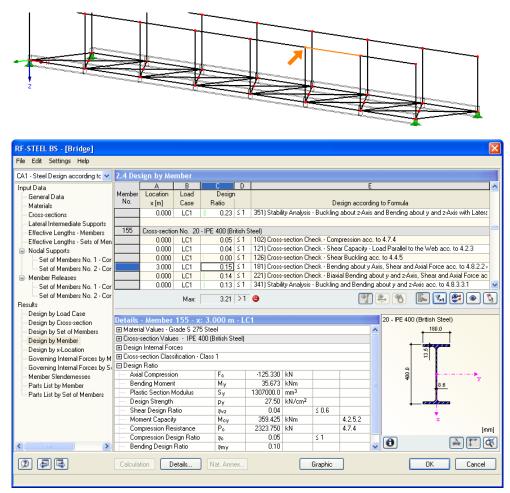


Figure 5.2: Selection of member and current *Location x* in RFEM model

If you move the RF-STEEL BS window to another place in the display and still cannot see the graphic clearly, use the so-called *View Mode* by clicking on the [Change View] button. The RF-STEEL BS window will be hidden so that you can adjust the view in the RFEM interface appropriately. The view mode provides the functions of the *View* menu, for example zooming, moving or rotating the display.

Click [Back] to return to the add-on module RF-STEEL BS.

### **RFEM work window**

It is also possible to visualize the design ratios directly in the structural model: Click the [Graphic] button to quit the add-on module RF-STEEL BS. The ratios are displayed in the RFEM work window like internal forces of a load case.



<u>G</u>raphic

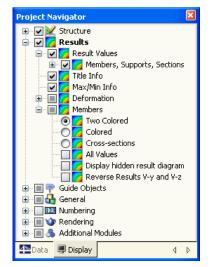


 x.xx To turn the display of design results on or off, use the button [Results on/off] shown on the left. To display the result values in the graphic, use the toolbar button [Show Result Values] to the right.

As the RFEM tables are of no relevance for the evaluation of RF-STEEL BS results, you may deactivate them.

The design cases can be set as usual by means of the list in the RFEM menu bar.

The graphical display of results can be set in the *Display* navigator by opening the *Results* folder and selecting the *Members* entry. By default, the ratios are shown *Two-Colored*.









If you select the *Colored* results display, the panel colors becomes available with various options for the multicolor display. Those are described in chapter 4.4.6 of the RFEM manual.

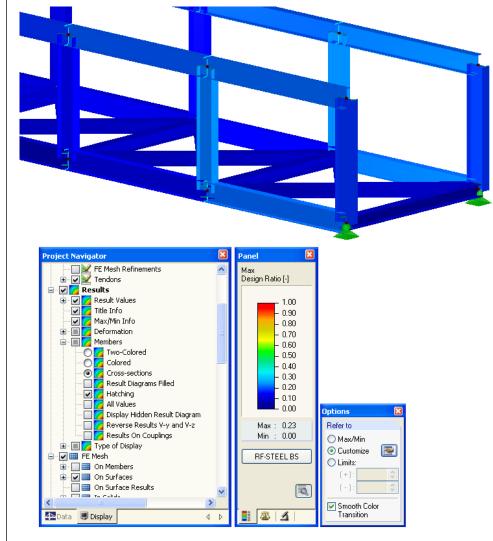


Figure 5.4: Design ratios with option Cross-sections in Display navigator



In the *Factors* tab, you can scale the design results, as you know it from the member internal forces. If you enter the factor 0 in the input field *Member Diagrams*, the results will be represented without scaling but with an increased line thickness.

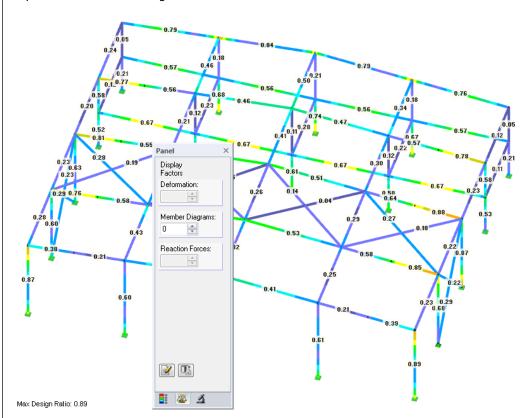


Figure 5.5: Panel tab Factors

The graphics can be transferred like any RFEM graphics to the printout report (see chapter 6.2 on page 49).

To return to the add-on module RF-STEEL BS, use the [STEEL BS] button in the panel.

**RF-STEEL BS** 

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# 5.2 Result Diagrams

In order to view the detailed distribution of results of a specific member, the graph of results can be used. Select the relevant member or set of members in the results table of RF-STEEL BS and then activate the diagram by the button as seen to the left. This button is located below the upper tables of results.

The result diagrams are available in the RFEM window via the main menu

 $\textbf{Results} \rightarrow \textbf{Member Results}$ 

or by using the corresponding button in the toolbar.

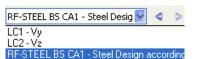
A new window is opened in which the result diagrams of the selected member or set of members are shown.

Result Diagram on Mem	ber	
🔃 🚃 🛛 RF-STEEL BS CA1 -	Steel 🖸 🖌 👂 🔁 🔍 🔍 🗃 🔜	🛛 📣 🗢 🐨 🛫 🔆 🥖 😽 📥 🛛 Men
Navigator 🖉 🗙	0.000 0.500 1.000 1.500 2.000 2.	.500 3.000 m x. 1.862 💭 [m] 🗌 Fixed
esign Kato	Design Ratio [-]	Design Ratio
		x Design Ratio [m] [-]
		MAX 0.000 0.22 A
		0.333 0.22
		R         R         0.667         0.22           HMX         1.000         0.22         I
		MAX 1.333 0.22
		MAX 1.667 0.22
		Max 2.000 0.22
		MAX 2.333 0.22 V
		Max/Min Only Edges Only
Results 4 D		
Location x: 1.862 m	Beginning X, Y, Z: 2	21.0, 0.0, 0.0 m End X,Y,Z: 18.0, 0.0, 0.0 m Order: 137 🚲

Figure 5.6: Result Diagram on Member dialog box

A particular design case can be selected from the list in the toolbar.

The *Result Diagram on Member* dialog box is described in detail in chapter 10.5 of the RFEM manual.





# 5.3 Filter Results

The structure of the RF-STEEL BS tables makes it already possible to select the results according to certain criteria. Additionally, you can use the filter functions as described in the RFEM manual to graphically evaluate the RF-STEEL BS results.

Firstly, you can use already defined partial views (cf RFEM manual, chapter 10.9, page 321) that group certain objects in a favorable way.

Secondly, you can set the stress ratios as criteria for filtering the results in the RFEM work window. For this, the so-called control panel is to be displayed. If it is not visible, you can switch it on in the main menu

#### View $\rightarrow$ Control panel

or by clicking on the corresponding button in the Results toolbar.

This panel is described in chapter 4.4.6 of the RFEM manual. The settings to filter the results are defined in the *Color Spectrum* tab of the panel. As this register is not available in case of the two colored stress display, it can be switched on by selecting one of the display options *Colored* or *Cross-Sections* in the *Display* navigator.

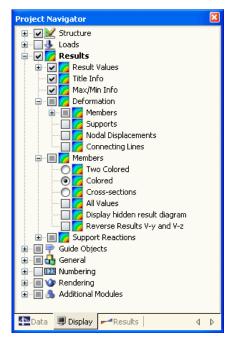


Figure 5.7: *Display* navigator: Results  $\rightarrow$  Members  $\rightarrow$  **Colored** 

For a colored view of the results, you can set in the panel that e.g. only design ratios greater than 0.1 are to be displayed. Furthermore, you can adjust the color spectrum in a way that one single color range exactly covers the design ratio 0.1 (see figure 5.8).

By the option *Display hidden result diagram* (*Display* navigator, entry Results  $\rightarrow$  Members), you can also display design results that do not satisfy the given conditions. Those design diagrams will then be drawn as dashed lines.



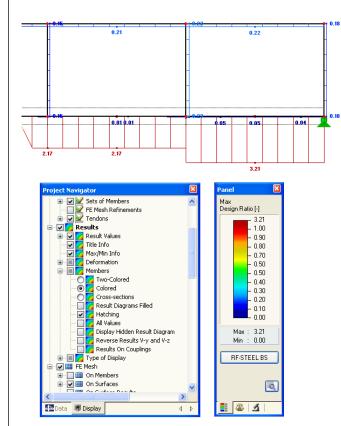


Figure 5.8: Filtering of stress ratios with adjusted color spectrum

#### Filtering Members

3 -

In the *Filter* tab of the control panel, you can enter the numbers of the members whose design ratios are to be shown in the graphics. This function is described in chapter 10.9 of the RFEM manual on page 326.

Contrary to the partial view function, the entire structure is displayed here. The following figure shows the design ratios in the compressed flange of a footbridge. The other members of this structure are also shown in the model but they are without any design ratios.

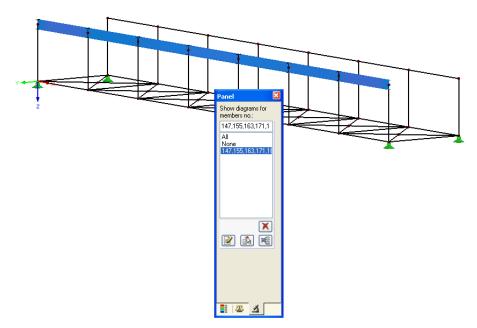


Figure 5.9: Filtering members: design ratios of footbridge flange



# 6. Printout

# 6.1 Printout Report

For the design results of RF-STEEL BS, a printout report can be created to which you can add graphics and comments. In this printout report, it is also possible to select the results tables of RF-STEEL BS that are to be printed.

The printout report is described in detail in the manual of the RFEM program. In particular, chapter 11.1.3.4 *Selecting Data of Add-on Modules* on page 338 is important. It deals with the selection of input and output data in all add-on modules.

For complex structures with a high number of design cases, it is recommended to split the data into several small printout reports which allows for a clearly-arranged printout and a faster work.

# 6.2 Print RF-STEEL BS Graphics

Every picture that is displayed in the graphic window of the main program RFEM can be included in the printout report. This means that the design ratios displayed in the RFEM model can be prepared for the printout, too. The graphics can be integrated in the global printout report or sent directly to the printer. Printing graphics is described in detail in the RFEM manual, chapter 11.2.

# Design results in RFEM model

To print the RF-STEEL BS graphic that is currently displayed in the RFEM work window,

select Print on the File menu

or use the toolbar button shown on the left.

🔊 RFEM 4.06 - [STEEL BS]									
4⊵	Eile	<u>E</u> dit	⊻iew	Insert	<u>C</u> alculate				
	2	<b>3</b> 1	<b>)</b>		<b>b</b> =				
9	Y	%	¶.	Pri 2	nt 🎮 🕶				

Figure 6.1: *Print* button in toolbar of main window

# **Result diagrams**

B

You can also print the result diagrams of members by clicking on the [Print] button in the *Result Diagram on Member* window.

🔇 Result Diagram on Men	ıber
RF-STEEL BS CA1 -	Steel D 🔽 🔹 👂 🔀
Navigator 🖉 🗙	0.000 0 Print
Design Ratio	Y
	Design Ratio [-]

Figure 6.2: Print button in toolbar of Result Diagram window

The following dialog box opens.



Graphic Printout						
General Options Color Spectrum	1					
Graphic Picture	Window To Print	Graphic Size				
🔿 Direct to Printer 💽	💿 Current Only	💿 As Screen View				
💿 In Printout Report: D1 🗸	🔿 AII 📃	🔿 Window Filling				
O To Clipboard		🔿 To Scale 1: 100 💌				
Graphic Picture Size	Options					
🔽 Use Whole Page Width	Show Printout Report on					
📃 Use Whole Page Height	[OK]					
🔲 Height: 🛛 52 🤹 [% of Page]	Show Results for Selected x-Location in the Result Diagram					
Rotation: 0 😂 [*]	Lock Graphic Pic	ure (without Update)				
Header of Graphic Picture						
RF-STEEL BS - Members Design I	Ratio, CA1					
		]				
٦		OK Cancel				

Figure 6.3: Graphic Printout dialog box, General tab

This dialog box is described in detail in chapter 11.2 on page 354 in the RFEM manual. The remaining two tabs *Options* and *Color Spectrum* are also explained there.

A RF-STEEL BS graphic that has been integrated in the printout report can be moved anywhere within the report by using the drag-and-drop function. In addition, it is possible to adjust imported graphics subsequently: Right-click the relevant entry in the navigator of the printout report and select *Properties* in the context menu. The dialog box *Graphic Printout* appears again, offering various options for adjustment.

Graphic Printout				
General Options Color S	pectrum			
Script O Proportional O Constant	Symbols Proportional Constant	Frame None Framed		
Factor: 1	Color			
<ul> <li>Standard (max 1000 x 1</li> <li>Maximal (max 5000 x 50</li> </ul>	<ul> <li>Greyscale</li> <li>Texts and Lines in Black</li> </ul>			
OUser Defined Max N of Pixe	⊙ All Colored			
D		OK Cancel		

Figure 6.4: Graphic Printout dialog box, Options tab

Remove from Printout Report Start with New Page

Selection... Properties



# 7. General Functions

This chapter describes some menu functions and export options of the design results.

# 7.1 RF-STEEL BS Design Cases

Members can be arranged in groups for different design cases. In this way, you can combine groups of structural components or analyze members with particular design specifications (for example changed materials, partial safety factors, optimization).

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

The RF-STEEL BS design cases are available in the RFEM work window and can be displayed like a load case or load group by means of the toolbar list.

### Create a new RF-STEEL BS case

To create a new design case,

select New Case on the File menu in the RF-STEEL BS add-on module.

The following dialog box appears.

New RF	-STEEL BS-Case
No. 2	Description Steel Design according to BS
Ø	OK Cancel

Figure 7.1: New RF-STEEL BS-Case dialog box

In this dialog box, enter a *No.* (which is not yet assigned) and a *Description* for the new design case. When you click [OK], table 1.1 *General Data* opens where you can enter the new design data.

### Rename a RF-STEEL BS case

To change the description of a design case subsequently,

select Rename Case on the File menu in the RF-STEEL BS add-on module.

The dialog box Rename RF-STEEL BS-Case appears.

Rename	RF-STEEL BS-Case
No.	Description
1	New Description 👻
٧	OK Cancel

Figure 7.2: Rename RF-STEEL BS-Case dialog box

RF-STEEL BS CA1 - Steel Desig V < > LC1 - Vy LC2 - Vz RF-STEEL BS CA1 - Steel Design according



### Copy a RF-STEEL BS case

To copy the input data of the current design case,

select Copy Case on the File menu in the RF-STEEL BS add-on module.

The dialog box *Copy RF-STEEL BS-Case* appears where you can specify the number and description of the new case.

Copy RF-STEEL BS-Case	×
Copy from Case	
CA1 - Steel Design according to BS	
New Case	
No.: Description:	
2 Design of Bottom Flange	
	Ξ
DK Cancel	

Figure 7.3: Copy RF-STEEL BS-Case dialog box

# **Delete RF-STEEL BS Case**

To delete design cases,

select Delete Case on the File menu in the RF-STEEL BS add-on module.

In the dialog box *Delete Cases*, you can select the relevant design case in the *Available Cases* list to delete it by clicking [OK].

Delete (	Cases	×
Available	e Cases	
No.	Description	^
1	Steel Design according to BS	
2	Design of Bottom Flange	
		×
1	OK Cance	

Figure 7.4: Delete Cases dialog box



# 7.2 Cross-Section Optimization

As mentioned in chapter 2.3, RF-STEEL BS offers you the possibility to optimize crosssections. Select the relevant cross-section by ticking its check box in column D or E in table 1.3 *Cross-sections* (see figure 2.10, page 16).

You can also start the cross-section optimization via the context menu in the results tables.

During the optimization, RF-STEEL BS determines the cross-section within the same crosssections table that fulfills the analysis requirements in the "optimal" way, i.e. comes as close as possible to the maximum allowable ratio specified in the *Details* dialog box, tab *Other* (see chapter 3.1). The required cross-section properties will be determined with the internal forces of RFEM. If a different cross-section proves to be more favorable, it will be used for the design. In this case, two cross-sections will be displayed on the right of table 1.3 as shown in figure 7.6 – the original cross-section from RFEM and the optimized one.

For parameterized cross-sections of the cross-section library, a dialog box with detailed specifications appears when you tick the check box for optimization.

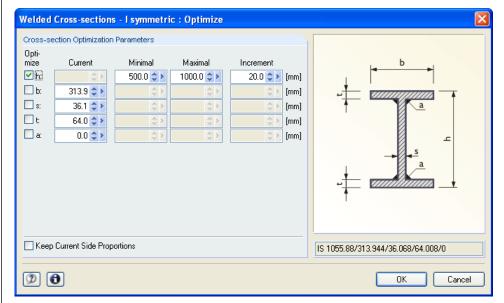


Figure 7.5: Welded Cross-Sections - I-Symmetric: Optimize dialog box

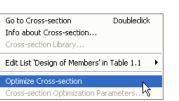
By ticking the check boxes in the *Optimize* column, you decide which parameter(s) you want to modify. The ticked check box enables the *Minimal* and *Maximal* columns where you specify the upper and lower limits of the parameter. The *Increment* column determines the interval in which the size of this parameter varies during the optimization process.

If you want to *Keep Current Side Proportions*, tick the corresponding check box. In addition, you have to select at least two parameters for the optimization.

Cross-sections composed of rolled cross-sections cannot be optimized.



Please note for the optimization process that the internal forces won't be recalculated automatically with the changed cross-sections. It is up to you to decide which cross-sections should be transferred to RFEM for a recalculation. As a result of optimized cross-sections, internal forces may vary considerably because of the changed stiffnesses in the structural system. It is recommended to recalculate the internal forces after the first optimization and then to optimize the cross-sections again.





You do not need to transfer the modified cross-sections to RFEM manually: Set table 1.3 *Cross-sections*, and then

select Export All Cross-sections to RFEM on the Edit menu.

The context menu in table 1.3 also provides options to export optimized cross-sections to RFEM.

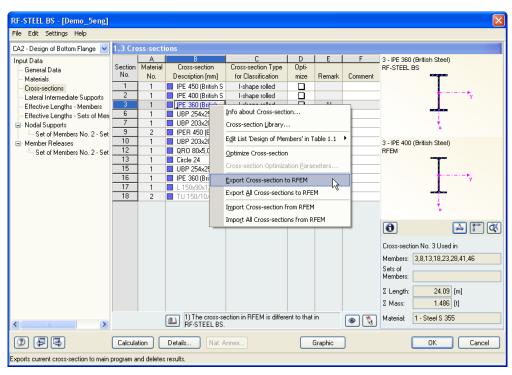


Figure 7.6: Context menu in table 1.3 Cross-Sections

Calculation

Before the changed cross-sections are transferred to RFEM, a question appears because exporting also implies deleting the results. When you confirm the query and then start the [Calculation] in RF-STEEL BS, the internal forces of RFEM and the design ratios of RF-STEEL BS are calculated in one calculation run.

	TEEL BS nation No. 20043
Do you want to	transfer the changed cross-sections to RFEM?
If so, the results	of RFEM and RF-STEEL BS will be deleted.
	Yes No

Figure 7.7: Question before transferring modified cross-sections to RFEM

By using the menu functions described above, you can also import the original RFEM crosssections to RF-STEEL BS. Please note that this option is only available in table 1.3 *Crosssections*.



If you optimize a tapered member, the program modifies the member's start and end and interpolates the second moments of area for the intermediate locations linearly. As these moments are considered with the fourth power, the designs may be inaccurate if the depths of the start and end cross-section differ considerably. In this case, it is recommended to divide the taper into several single members whose start and end cross-sections have minor cross-section differences.



# 7.3 Import / Export of Materials

If you change a material in table 1.2 of RF-STEEL BS, you can export it to RFEM like crosssections or also reload the original material from RFEM to the module. The materials that have been modified in the module are marked in blue color.

You do not need to transfer the modified materials to RFEM manually. Set table 1.2 *Materials*, and then

select Export All Materials to RFEM on the Edit menu.

The context menu of table 1.2 also provides options to transfer modified materials to RFEM.

Input Data       A       B         General Data       Material       Material         Materials       Comment       Comment         Cross-sections       Lateral Intermediate Supports       Effective Lengths - Stei of Men         Effective Lengths - Stei of Men       Set of Members No. 2 - Set       Material Properties         Member Releases       Export All Materials from RFEM       MPa         Poisson's Ratio       A       0.300         Unit Weight       y       78846.200         MPa       Naterial Export All Materials from RFEM         Import All Materials from RFEM       MPa         Poisson's Ratio       A       0.300         Unit Weight       y       78846.200         MPa       Oxall Supports       Set of Members No. 2 - Set         Material Expansion       a       1.2000E-05       1/°C         Partial Safety Factor       7M       1.00       Export All Material Trickness       1         Yield Strength       Py       355.000       MPa       Sections:         Yield Strength       Py       335.000       MPa       Sections:         Yield Strength       Py       325.000       MPa       Set of Members:       Set of Members:         Y	Materials				
General Data       Material       Material       Comment         Cross-sections       Lateral Intermediate Supports       Image: Comment Stress of the section		В			
No.       Description       Comment         Cross-sections       I       Grade S 275 Steel IBS 590-1:200       Image: Steel IBS 590-1:200         Lateral Intermediate Supports       Effective Lengths - Members       Material Library         Effective Lengths - Sets of Mem       Image: Steel IBS 590-1:200       Image: Steel IBS 590-1:200         Nodal Supports       Set of Members No. 2 - Set       Image: Steel IBS 590-1:200       Image: Steel IBS 590-1:200         Material Comment       Image: Steel IBS 590-1:200       Image: Steel IBS 590-1:200       Image: Steel IBS 590-1:200         Nodal Supports       Set of Members No. 2 - Set       Image: Steel IBS 590-1:200       Image: Steel IBS 590-1:200       Image: Steel IBS 590-1:200         Member Releases       Set of Members No. 2 - Set       Image: Steel IBS 590-1:200       Image: Steel IBS 590-1:200       Image: Steel IBS 590-1:200         Set of Members No. 2 - Set       Image: Steel IBS 590-1:200       Image: Steel IBS 590-1:200       Image: Steel IBS 590-1:200       Image: Steel IBS 590-1:200         Set of Members No. 2 - Set       Image: Steel IBS 590-1:200       Image: Steel IBS 590-1:200       Image: Steel IBS 590-1:200       Image: Steel IBS 590-1:200         Set of Members No. 2 - Set       Image: Steel IBS 590-1:200       Image: Steel IBS 590-1:200       Image: Steel IBS 590-1:200       Image: Steel IBS 590-1:200         Set of					
Clussedulurs       Clussedulurs       Material Library         Lateral Intermediate Supports       Effective Lengths - Sets of Members         Effective Lengths - Sets of Members No. 2 - Set       Material Properties         Member Releases       Set of Members No. 2 - Set         Set of Members No. 2 - Set       Material Properties         Import Materials from RFEM       Import Materials from RFEM         Set of Members No. 2 - Set       Material C Thermal Expansion         Autorial From Set Modulus       G         Obsign Relevant       Material Set MPa         Vield Strength       Py         Max. Structural Thickness       t1         Yield Strength       Py         Max. Structural Thickness       t2         Yield Strength       Py         Max. Structural Thickness       t3         Set of Members       t3         Yield Strength       Py         Max. Structural Thickness       t2         Yield Strength       Py         Max. Structural Thickness       t3         66:69,71-74         Max. Structural Thickness       t3         Set of       Group         Yield Strength       Py         Max. Structural Thickness       t3	Description	Comment			
Effective Lengths - Members         Effective Lengths - Sets of Men         Nodal Supports         Set of Members No. 2 - Set         Member Releases         Set of Members No. 2 - Set         Member Releases         Set of Members No. 2 - Set         Modulus of Elasticity         Import All Materials from RFEM         Import All Materials from RFEM         Options - Ratio         Autorial Library         Poisson's Ratio         Autorial Library         Modulus of Elasticity         Import All Materials from RFEM         Import All Materials from RFEM         Design Relevant         Yield Strength         Yield Strength         Max Structural Thickness         Yield Strength         Py         Max Structural Thickness         Yield Strength         Py         Max Structural Thickness       t3         Yield Strength       Py         Py       325.000         Members:       66-69.71-74         Material Thickness       t3         Material No. 2 Used in         Yield Strength       Py         Py       325.000					
Effective Lengths - Sets of Members Effective Lengths - Sets of Members No. 2 - Set Material Properties Export Material to RFEM Export Materials to RFEM Import Materials from RFEM Import Materials from RFEM Shear Modulus of Elasticity Shear Modulus of Elasticity Shear Modulus of Elasticity Shear Modulus of Clasticity Waterial No. 2. Used in Cross-sections: Yield Strength Yield Strength Yield Strength Py 345.000 MPa Max. Structural Thickness ti 3 Stude Strength Py 325.000 MPa Sections: <td>Grade S 355 Steel LBS 5950 1.00</td> <td></td> <td></td> <td></td> <td></td>	Grade S 355 Steel LBS 5950 1.00				
<ul> <li>Nodal Suppots</li> <li>Set of Members No. 2 - Set</li> <li>Material Properties</li> <li>Material Properties</li> <li>Ingort Material from RFEM</li> <li>Ingort All Materials from RFEM</li> <li>Modulus of Elasticity</li> <li>Shear Modulus</li> <li>G</li> <li>G</li> <li>T8846 200</li> <li>MPa</li> <li>Poisson's Ratio</li> <li>Unit Weight</li> <li>T7850</li> <li>IV/m<sup>3</sup></li> <li>Coefficient of Thermal Expansion</li> <li>a</li> <li>1.200E-05</li> <li>I/°C</li> <li>Partial Safety Factor</li> <li>Yield Strength</li> <li>Max. Structural Thickness</li> <li>It</li> <li>Max. Structural Thickness</li> <li>It</li> <li>Gait Gait</li> <li>Gait Gait</li> <li>Material No. 2 Used in Cross-sections:</li> <li>Material Strength</li> <li>Max. Structural Thickness</li> <li>It</li> <li>Gait Gait</li> <li>Gait</li></ul>	<u>Material Lit</u>	Library			
A Nodal Supports       Export All Materials to RFEM       %         Set of Members No. 2 - Set       Material Properties       Import Material from RFEM         Bernort All Materials from RFEM       MPa         Modulus of Elasticity       G       79846.200         Outlint Weight       y       78.50         Coefficient of Themal Expansion       α       1.2000E-05         Partial Safety Factor       ym       1.00         Descript Relevant       Yield Strength       Py         Yield Strength       Py       345.000         Max. Structural Thickness       tz       4.00         Yield Strength       Py       345.000         Max. Structural Thickness       tz       4.00         Yield Strength       Py       345.000         Max. Structural Thickness       tz       4.00         Yield Strength       Py       345.000         Max. Structural Thickness       tz       4.00         Yield Strength       Py       345.000         Max. Structural Thickness       tz       66-69,71-74         Sets of       Yield Strength       Py       325.000         Members:       Sets of       Members:       56-69,71-74	Export Mar	Material to RFEM			
Material Properties     Import Material from RFEM       Import Material from RFEM     Import Materials from RFEM       Member Releases     Import All Materials from RFEM       Shear Modulus     G       Outling Shear Modulus     G       Poisson's Ratio     µ       University     0.300       University     Y       The Statisticity     Y       Shear Modulus     G       Poisson's Ratio     µ       University     Y       The Statisticity     Y       The Statistis     Statisti		All Motorials to REEM			
■ RFEM Relevant     Import Material from RFEM     MPa       Set of Members No. 2 - Set     ■ RFEM Relevant     Import All Materials from RFEM     MPa       Shear Modulus     G     78846.200     MPa       Poisson's Ratio     µ     0.300       Unit Weight     y     78.50     kN/m³       Coefficient of Thermal Expansion     α     1.2000E-05     1/°C       Partial Safety Factor     ym     1.00     Expansion       Design Relevant     Yield Strength     py     355.000       Yield Strength     py     345.000     MPa       Max. Structural Thickness     t1     1.600     cm       Yield Strength     py     345.000     MPa       Max. Structural Thickness     t2     4.00     cm       Yield Strength     py     335.000     MPa       Max. Structural Thickness     t3     6.30     cm       Yield Strength     py     325.000     MPa		All Materials to Krizm	-		
Set of Weindels No. 2 * Set         Modulus of Elasticity         Import All Materials from RFEM         MPa           Shear Modulus         G         78846.200         MPa           Poisson's Ratio         µ         0.300           Unit Weight         y         78.50         kN/m³           Coefficient of Thermal Expansion         α         1.2000E+05         1/°C           Patial Safety Factor         ym         1.00         Environment           Vield Strength         py         355.000         MPa           Max. Structural Thickness         t1         1.60         cm           Yield Strength         py         345.000         MPa           Max. Structural Thickness         t2         4.00         cm           Yield Strength         py         335.000         MPa           Max. Structural Thickness         t3         6.30         cm           Yield Strength         py         325.000         MPa           Max. Structural Thickness         t3         6.6.90         m           Yield Strength         py         325.000         MPa		Material from RFEM			
Inclusion         G         78846.200         MPa           Shead Modulus         G         78846.200         MPa           Poisson's Ratio         µ         0.300           Unit Weight         γ         78.50         kN/m3           Coefficient of Thermal Expansion         α         1.200E-05         1/°C           Partial Safety Factor         γ         γ         355.000         MPa           Max. Structural Thickness         t1         1.60         cm         Cross-sections:         9           Max. Structural Thickness         t2         4.00         cm         Yield Strength         py         345.000         MPa           Max. Structural Thickness         t2         4.00         cm         Sections:         9           Max. Structural Thickness         t2         66-69,71-74         Sections:         Sections: <t< td=""><td></td><td>All Materials from RFEM</td><td></td><td></td><td></td></t<>		All Materials from RFEM			
Poisson's Ratio $\mu$ 0.300           Unit Weight         y         78.50         N/m <sup>3</sup> Coefficient of Themal Expansion $\alpha$ 1.2000E-05         1/°C           Partial Safety Factor         ym         1.100         Image: Comparison of the	Hodalds of Eldstoky				
Unit Weight         γ         78.50         kN/m³           Coefficient of Thermal Expansion         α         1.2000E+05         1/°C           Patial Safety Factor         γM         1.00           Design Relevant			МГа		
Coefficient of Thermal Expansion         α         1.200E-05         1/°C           Partial Safety Factor         γм         1.00           Design Relevant         γm         1.00           Yield Strength         py         355.000         MPa           Max. Structural Thickness         t1         1.60         cm           Yield Strength         py         345.000         MPa           Max. Structural Thickness         t2         4.00         cm           Yield Strength         py         335.000         MPa           Max. Structural Thickness         t2         4.00         cm           Yield Strength         py         335.000         MPa           Max. Structural Thickness         t3         6.30         cm           Yield Strength         py         325.000         MPa			kN/m <sup>3</sup>		
Partial Safety Factor         γм         1.00           □ Design Relevant					
Design Relevant         Py         355.000         MPa           Yield Strength         Py         345.000         MPa           Max. Structural Thickness         t1         1.60         cm           Yield Strength         Py         345.000         MPa           Max. Structural Thickness         t2         4.00         cm           Yield Strength         Py         335.000         MPa           Max. Structural Thickness         t2         66-69,71-74           Max. Structural Thickness         t3         6.30         cm           Yield Strength         Py         325.000         MPa	•				
Yield Strength         Py         355.000         MPa           Max. Structural Thickness         t1         1.60         cm         Cross- sections:           Yield Strength         py         345.000         MPa         sections:         9           Max. Structural Thickness         t2         4.00         cm         sections:         9           Max. Structural Thickness         t2         6.00         mPa         sections:         9           Max. Structural Thickness         t3         6.30         cm         Seto f         Seto f           Yield Strength         py         325.000         MPa         Seto f         Seto f         Seto f		////			
Max. Structural Thickness         t1         1.60         cm         Cross-sections:         9           Yield Strength         py         345.000         MPa         Sections:         9           Max. Structural Thickness         t2         4.00         cm         Members:         66-69,71-74           Max. Structural Thickness         t3         6.30         cm         Sets of         Members:         64-69,71-74           Vield Strength         py         325.000         MPa         Members:         64-69,71-74	-	Py 355.000	MPa 📒	Material No. 211sed in	
Yield Strength         py         345.000         MPa         sections:         9           Max. Structural Thickness         tz         4.00         cm         400         cm         66-69,71-74         66-69,71-74         66-69,71-74         56-59,71-74         56-					
Yield Strength         py         335,000         MPa         Members:         66-69,71-74           Max. Structural Thickness         t3         6.30         cm         Sets of Members:         Members:         64-69,71-74		Py 345.000	MPa		
Max Structural Thickness to 6.30 cm Sets of Members:					
Yield Strength Py 325.000 MPa Members:		Py 335.000	MPa		
The Storight py 323,000 MPa					
				Members:	
	Max. Structural Thickness t4			Σ Length: 50.00	[m]
Yield Strength py 315.000 MPa				-	
Max. Structural Thickness to 10.00 cm 🖌 2 Mass: 4./49	Max. Structural Thickness to	ts 10.00	cm 💌	2 Midss	19
<b>x</b>					

Figure 7.8: Context menu in table 1.2 Materials

#### <u>Calculation</u>

Before the changed materials are transferred to RFEM, a question appears because exporting also implies deleting the results. When you confirm the query and then start the [Calculation] in RF-STEEL BS, the internal forces of RFEM and the design ratios of RF-STEEL BS are calculated in one calculation run.

RF-STEEL BS Information No. 20043
Do you want to transfer the changed materials to RFEM?
If so, the results of RFEM and RF-STEEL BS will be delete

Figure 7.9: Question before transferring modified materials to RFEM



# 7.4 Units and Decimal Places

The units and decimal places for RFEM and all add-on modules are managed in one global dialog box. In the add-on module RF-STEEL BS, you can use the menu to define the units. To open the corresponding dialog box,

select Units and Decimal Places on the Settings menu.

The program opens the following dialog box that you already know from RFEM. The add-on module RF-STEEL BS is preset.

Units and Decimal Places	- CZ *					X
Program / Module RF-STEEL Surfaces RF-STEEL Members RF-STEEL EC3 RF-STEEL AISC RF-STEEL SIA RF-STEEL SIA RF-STEEL BS RF-KAPPA RF-LTB	- CZ * RF-STEEL BS Output Data Stresses: Design Ratios: Unitless:	Unit kN/cm^2	Dec. Places	Parts List Lengths: Total Lengths: Surface Areas: Volumes: Masses per Length:	Unit m v m^2 v m^3 v kg/m v	Dec. Places 2 <b>‡</b> 2 <b>‡</b> 2 <b>‡</b> 2 <b>‡</b> 2 <b>‡</b>
RF-FE-LTB RF-EL-PL RF-C-TO-T PLATE-8UCKLING RF-ASD CRANEWAY RF-CONCRETE Surfac RF-CONCRETE Memb RF-CONCRETE Colum				Masses per Length: Masses: Total Masses:	kg/m V kg V t V	2 🗘
- RF-PUNCH - RF-TIMBER Pro - RF-TIMBER - RF-DYNAM - RF-END-PLATE - RF-CONNECT - RF-FRAMEJOINT Pro - RF-FRAMEJOINT - RF-DSTV						
	9				ОК	Cancel

Figure 7.10: Units and Decimal Places dialog box

📳 📄

The settings can be saved as a user profile to reuse them in other structures. The corresponding functions are described in chapter 12.6.2 of the RFEM manual.

# 7.5 Export Results

The design results can be transferred to other programs in various ways.

# Clipboard

Select the relevant cells in the results table of RF-STEEL BS and copy them to the clipboard via [Ctrl]+[C]. The contents can then be inserted via [Ctrl]+[V] to e.g. some word processing program. The headers of the table columns are not exported.

# **Printout Report**

The RF-STEEL BS data can be printed to the global printout report (see chapter 6.1, page 49) and then be exported via the printout report menu

#### File $\rightarrow$ Export to RTF File or BauText.

This function is described in chapter 11.1.11 of the RFEM manual on page 350.



# Excel / OpenOffice

RF-STEEL BS enables you to directly export data to MS Excel or OpenOffice.org Calc. To open the corresponding dialog box,

select Export Tables on the File menu in the RF-STEEL BS add-on module.

The following export dialog box appears.

Export - MS Excel	×
Table Parameters	Application
🗹 With Table Header	<ul> <li>Microsoft Excel</li> </ul>
Only Marked Rows	OpenOffice.org Calc
Transfer Parameters	
Export Table to Active Work	
Rewrite Existing Worksheet	
Selected Tables	
<ul> <li>Active Table</li> </ul>	Export Tables with Details
🔿 All Tables	Details
🗹 Input Tables	
Result Tables	
	OK Cancel

Figure 7.11: Export - MS Excel dialog box

When you have selected the relevant parameters, start the export by clicking [OK]. Excel or OpenOffice will be started automatically. It is not necessary to run the programs in the background.

	Α	В	С	D	Е	F				
1	Member	Location	Load	Design	1					
2	No.	× [m]	Case	Ratio		Design according to Formula				
3	1	1 Cross-section No. 1 - IPE 500 (British Steel)								
4		6,000	LC5	0,00	≤1	00) No or Very Small Internal Forces				
5		0,000	LC6	0,00	≤1	01) Cross-section Check - Tension acc. to 4.6				
6		0,000	LC1	0,02	≤1	102) Cross-section Check - Compression acc. to 4.7.4				
7		5,400	LC3	0,02	≤1	111) Cross-section Check - Bending about y-Axis for Low Shear acc. to 4.2.5.2 - Clas				
8		3,000	LC4	0,05	≤1	116) Cross-section Check - Bending about z-Axis for Low Shear acc. to 4.2.5.2 - Ck				
9		0,000	LC2	0,01	≤1	121) Cross-section Check - Shear Capacity - Load Parallel to the Web acc. to 4.2.3				
10		6,000	LC4	0,00	≤1	23) Cross-section Check - Shear Capacity - Load Parallel to the Flange acc. to 4.2.3				
11		0,000	LC1	0,00	≤1	26) Cross-section Check - Shear Buckling acc. to 4.4.5				
12		6,000	LC2	0,11	≤1	81) Cross-section Check - Bending about y Axis, Shear and Axial Force acc. to 4.8.2				
13		3,000	LC6	0,06	≤1	22) Lateral Torsional Buckling according to 4.3 and B.2 (I, H and Channel Cross-Section				
14		0,000	LC1	0,08	≤1	341) Stability Analysis - Buckling and Bending about y and z-Axis acc. to 4.8.3.3.1				
15		3,000	LC2	0,15	≤1	351) Stability Analysis - Buckling about z-Axis and Bending about y and z-Axis with La				
16										
17	2	Cross-sectio	n No. 1 -	IPE 500 (Brit	ish Ste	el)				
18		6,000	LC5	0,00	≤1	100) No or Very Small Internal Forces				
19		0,000	LC6	0,00	≤1	101) Cross-section Check - Tension acc. to 4.6				
20		0,000	LC1	0,02	≤1	102) Cross-section Check - Compression acc. to 4.7.4				
21		6,000	LC3	0,02	≤1	111) Cross-section Check - Bending about y-Axis for Low Shear acc. to 4.2.5.2 - Clas				
22		3,000	LC4	0,05	≤1	116) Cross-section Check - Bending about z-Axis for Low Shear acc. to 4.2.5.2 - Cla				
23		0,000	LC2	0,01	≤1	121) Cross-section Check - Shear Capacity - Load Parallel to the Web acc. to 4.2.3				
24		6,000	LC4	0,00	≤1	123) Cross-section Check - Shear Capacity - Load Parallel to the Flange acc. to 4.2.3				
25		0,000	LC1	0,00	≤1	126) Cross-section Check - Shear Buckling acc. to 4.4.5				
26		6,000	LC2	0,11	≤1	181) Cross-section Check - Bending about y Axis, Shear and Axial Force acc. to 4.8.2				

Figure 7.12: Results in Excel

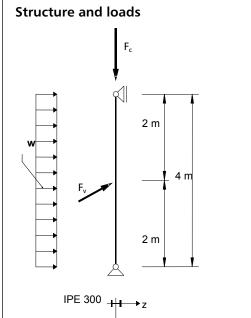


# 8. Example

# Column with Biaxial Bending

In the following example, we perform the governing stability designs of flexural buckling and lateral-torsional buckling for a column with biaxial bending. The calculation described below follows the *Load and Resistance Factor Design* provisions.

# **Design values**

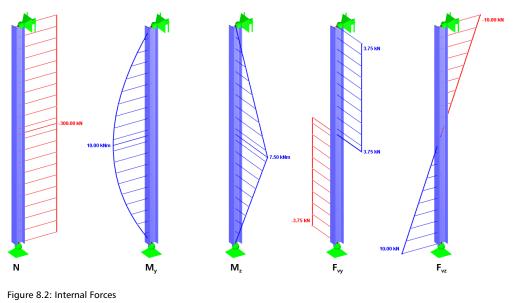


Design values of static loads:

$F_{c} = 300 \text{ kN}$	
w = 5.0  kN/m	
$F_{v} = 7.5 \text{ kN}$	
Cross-section:	IPE 300
Material:	Steel Grade S 275

Figure 8.1: Structure and design loads (γ-fold)

### Internal forces according to linear static analysis





### Design location (decisive location x)

The design is performed by x-location, i.e. on defined locations x of the equivalent member. The decisive location is x = 2.00 m with the following internal forces of RFEM:

 $F_c = -300.00 \text{ kN}$   $M_v = 10.00 \text{ kNm}$   $M_z = 7.50 \text{ kNm}$   $F_{vv} = 3.75 \text{ kN}$   $F_{vz} = 0.00 \text{ kN}$ 

### **Cross-section properties - IPE 300**

Cross-Section Properties	Symbol	Value	Unit
Gross area	A <sub>g</sub>	53.80	cm <sup>2</sup>
Moment of inertia about major axis	l <sub>y</sub>	8356.00	cm <sup>4</sup>
Moment of inertia about minor axis	l <sub>z</sub>	604.00	cm <sup>4</sup>
Radius of gyration about major axis	r <sub>y</sub>	12.5	cm
Radius of gyration about minor axis	r <sub>z</sub>	3.35	cm
Cross-section weight	w <sub>t</sub>	42.2	kg/m
Torsion constant	J	19.90	cm <sup>4</sup>
Warping constant	C <sub>w</sub>	126000.00	cm <sup>6</sup>
Elastic section modulus about major axis	Zy	557.00	cm³
Elastic section modulus about minor axis	Z <sub>z</sub>	80.50	cm <sup>3</sup>
Plastic section modulus about major axis	Sy	628.00	cm <sup>3</sup>
Plastic section modulus about minor axis	Sz	125.22	cm <sup>3</sup>
Strut curve for buckling about major axis	SC <sub>y</sub>	а	
Strut curve for buckling about minor axis	SCz	b	

### Material properties – steel grade S275

Material Properties	Symbol	Value	Unit
Modulus of elasticity	E	205000	N/mm <sup>2</sup>
Modulus of rigidity	G	78865	N/mm <sup>2</sup>
Yield strength	py	275	N/mm <sup>2</sup>

# **Classification of cross-section**

 $\varepsilon = \sqrt{275 / p_y} = \sqrt{275 / 275} = 1.0$ 

#### **Classification of flange**

$$\begin{split} b &= 75 \text{ mm} \\ T &= 10.7 \text{ mm} \\ \lambda_{f,1} &= 8 \varepsilon = 8 \cdot 1.0 = 8 \\ \lambda_{f,2} &= 9 \varepsilon = 9 \cdot 1.0 = 9 \\ \lambda_{f,3} &= 13 \varepsilon = 13 \cdot 1.0 = 13 \\ \frac{b}{T} &= \frac{75}{10.7} = 7 \leq 8 = \lambda_{f,1} \end{split}$$

Class of the flange is 1.



#### **Classification of web**

 $\begin{aligned} \sigma_{w,A} &= -40.9 \text{ N} / \text{mm}^2 \\ \sigma_{w,B} &= -70.6 \text{ N} / \text{mm}^2 \\ d &= 278.6 \text{ mm} \\ t &= 7.1 \text{ mm} \\ r_1 &= \frac{F}{d \cdot t \cdot p_{yw}} = \frac{300 \cdot 10^3}{278.6 \cdot 7.1 \cdot 275} = 0.552 \\ r_2 &= \frac{F}{A} / (p_y) = \frac{300 \cdot 10^3}{54.9 \cdot 10^2} / (250 / 1.1) = 0.240 \\ \lambda_{w,1} &= \frac{84 \epsilon}{1 + r_1} = \frac{84 \cdot 1.0}{1 + 0.939} = 43.329 \\ \lambda_{w,2} &= \frac{105 \epsilon}{1 + 1.5 r_1} = \frac{105 \cdot 1.0}{1 + 1.5 \cdot 0.939} = 43.604 \\ \lambda_{w,3} &= \frac{126 \epsilon}{1 + 2 r_2} = \frac{126 \cdot 1.0}{1 + 2 \cdot 0.240} = 85.085 \\ \frac{d}{t_{fw}} &= \frac{206.8}{6.8} = 30.412 \le 43.329 = \lambda_{w,1} \\ \end{aligned}$  Class of the web is 1.

Class of the cross-section is 1.

#### **Classification in RF-STEEL BS**

Flange					
· Width	b	75.0	mm		Table 11
- Thickness	Т	10.7	mm		Table 11
- Constant	ε <sub>f</sub>	1.000			Table 11
· Maximal Ratio for Class 1	λ <sub>f,1</sub>	9.000			Table 11
· Maximal Ratio for Class 2	$λ_{f,2}$	10.000			Table 11
Maximal Ratio for Class 3	λ <sub>f,3</sub>	15.000			Table 11
Ratio	b/T	7.009		$\leq \lambda_{f.1}$	
- Class of Flange		1			Table 11
Neb					
Stress at Web Start	$\sigma_{w,A}$	-40.9	N/mm <sup>2</sup>		
- Stress at Web End	$\sigma_{w,B}$	-70.6	N/mm <sup>2</sup>		
Depth	d	278.6	mm		Table 11
- Thickness	t	7.1	mm		Table 11
- Gross Area	A <sub>α</sub>	5380	mm²		
Design Strength of the Web	p <sub>vw</sub>	275.0	N/mm <sup>2</sup>		
- Axial Compressive Force	Fc	-300.00	kN		
Constant	ε <sub>w</sub>	1.000			Table 11
- Stress Ratio	r <sub>1</sub>	0.552			3.5.5
Stress Ratio	r <sub>2</sub>	0.203			3.5.5
Maximal Ratio for Class 1	$\lambda_{w.1}$	51.563			Table 11
Maximal Ratio for Class 2	λ <sub>w.2</sub>	54.727			Table 11
Maximal Ratio for Class 3	λ <sub>w.3</sub>	85.376			Table 11
Ratio	d/t	39.239		$\leq \lambda_{w,1}$	
Class of Web		1			Table 11
Class of Cross-Section		1			Table 11



# Buckling about y-axis (major axis)

$$KL_{v} = 4.0 \text{ m}$$

t = 10.7 mm < 40 mm  $\Rightarrow$  strut curve a

Slenderness

$$\lambda_{y} = \frac{KL_{y}}{r_{y}} = \frac{4000}{125} = 32.1$$

Limit slenderness

$$\lambda_0 = 0.2 \sqrt{\left(\frac{\pi^2 E}{p_y}\right)} = 0.2 \sqrt{\left(\frac{3.1415^2 \cdot 205000}{275}\right)} = 17.155$$

Robertson constant for strut curve a:  $a_y = 2.0$ 

Perry factor

$$\eta_y = \alpha (\lambda_y - \lambda_0) / 1000 = \frac{2.0(32.1 - 17.155)}{1000} = 0.03$$

Euler buckling stress

$$p_{Ey} = \frac{\pi^2 E}{\lambda_y^2} = \frac{3.1415^2 \cdot 205000}{32.1^2} = 1964.04 \text{ MPa}$$

Buckling factor

$$\phi_y = \frac{p_y + (\eta_y + 1)p_{Ey}}{2} = \frac{275 + (0.03 + 1) \cdot 1964.04}{2} = 1148.86 \text{ MPa}$$

Compressive strength

$$p_{cy} = \frac{p_y \cdot p_{Ey}}{\phi_y \cdot \sqrt{(\phi_y^2 - p_{Ey} \cdot p_y)}} = \frac{275 \cdot 1964.04}{1148.86 \cdot \sqrt{(1148.86^2 - 275 \cdot 1964.04)}} = 265.84 \text{ MPa}$$

Compression resistance

 $P_{cy} = p_{cy} \cdot A_g = 265.84 \cdot 5380 = 1430.08 \text{ kN}$ 

**Design Ratio** 

 $\eta=~F_c~/~P_{cy}=~300.0~/~1430.08~=~0.21$ 

- O.K.

#### Design in RF-STEEL BS

Axial Compression	F	300.00	kN		
Design Strength	p <sub>v</sub>	275.000	N/mm <sup>2</sup>		
Modulus of Elasticity	E	205000.000	N/mm <sup>2</sup>		
Nominal Effective Length	KLγ	4000.000	mm		
Radius of Gyration	r <sub>v</sub>	124.626	mm		
Slenderness	λγ	32.096			4.7.2
Limiting Slenderness	λο	17.155			C.2
Strut Curve	SC <sub>y</sub>	а			Table 23
Robertson Constant	av	2.000			C.2
Perry Factor	η <sub>v</sub>	0.030			C.2
Factor	φ <sub>v</sub>	1148.860	N/mm <sup>2</sup>		C.1
Euler Buckling Stress	P <sub>Ey</sub>	1964.040	N/mm <sup>2</sup>		C.1
Compressive Strength	p <sub>cy</sub>	265.814	N/mm <sup>2</sup>		C.1
Gross Area	Aq	5380.000	mm <sup>2</sup>		
Compression Resistance	P <sub>cy</sub>	1430.08	kN		4.7.4 / 4.7.5
Design Ratio	η	0.21		< 1.0	4.7.4



# Buckling about z-axis (minor axis)

$$KL_{z} = 4.0 \text{ m}$$

t = 10.7 mm < 40 mm  $\Rightarrow$  strut curve b

Slenderness

$$\lambda_z = \frac{KL_z}{r_z} = \frac{4000}{33.5} = 119.4$$

Limit slenderness

\_

$$\lambda_0 = 0.2 \sqrt{\left(\frac{\pi^2 E}{p_y}\right)} = 0.2 \sqrt{\left(\frac{3.1415^2 \cdot 205000}{275}\right)} = 17.155$$

Robertson constant for strut curve b:  $a_z = 3.5$ 

Perry factor

$$\eta_z = \alpha (\lambda_z - \lambda_0) / 1000 = \frac{3.5 \cdot (119.4 - 17.155)}{1000} = 0.358$$

Euler buckling stress

$$p_{Ez} = \frac{\pi^2 E}{\lambda_z^2} = \frac{3.1415^2 \cdot 205000}{119.4^2} = 141.97 \text{ MPa}$$

**Buckling factor** 

$$\phi_z = \frac{p_y + (\eta_z + 1)p_{Ez}}{2} = \frac{275 + (0.358 + 1) \cdot 141.97}{2} = 233.88 \text{ MPa}$$

Compressive strength

$$p_{cz} = \frac{p_y \cdot p_{Ez}}{\phi_z \cdot \sqrt{(\phi_z^2 - p_{Ez} \cdot p_y)}} = \frac{275 \cdot 141.97}{233.88 \cdot \sqrt{(233.88^2 - 275 \cdot 141.97)}} = 108.74 \text{ MPa}$$

**Compression resistance** 

 $P_{cz} = p_{cz} \cdot A_g = 108.74 \cdot 5380 = 585.04 \text{ kN}$ 

Design Ratio

 $\eta=~F_c~/~P_{cz}=~300.0~/~585.04~=~0.51$ 

#### - O.K., decisive

#### Design in RF-STEEL BS

			-		
Axial Compression	Fc	300.00	kN		
Design Strength	p <sub>v</sub>	275.000	N/mm <sup>2</sup>		
Modulus of Elasticity	E	205000.000	N/mm <sup>2</sup>		
Nominal Effective Length	KL <sub>z</sub>	4000.000	mm		
Radius of Gyration	r <sub>z</sub>	33.5	mm		
Slenderness	λ <sub>z</sub>	119.4			4.7.2
Limiting Slenderness	λο	17.155			C.2
Strut Curve	SCz	b			Table 23
Robertson Constant	az	3.500			C.2
Perry Factor	$\eta_z$	0.358			C.2
Factor	φ <sub>z</sub>	233.88	N/mm <sup>2</sup>		C.1
Euler Buckling Stress	p <sub>Ez</sub>	141.97	N/mm <sup>2</sup>		C.1
Compressive Strength	р <sub>сz</sub>	108.74	N/mm <sup>2</sup>		C.1
Gross Area	A <sub>g</sub>	5380.000	mm <sup>2</sup>		
Compression Resistance	P <sub>cz</sub>	585.04	kN		4.7.4 / 4.7.5
Design Ratio	η	0.51		< 1.0	4.7.4



# Lateral-torsional buckling

Effective length for lateral-torsional buckling

 $KL_{LT} = 4.0 \text{ m}$ 

Slenderness

$$\lambda = \frac{KL_{LT}}{r_z} = \frac{4000}{33.5} = 119.38$$

Limit equivalent slenderness

$$\lambda_{L0} = 0.4 \sqrt{\left(\frac{\pi^2 E}{p_y}\right)} = 0.4 \sqrt{\left(\frac{3.1415^2 \cdot 205000}{275}\right)} = 34.31$$

Equivalent slenderness

$$\begin{split} \lambda_{LT} &= uv\lambda\sqrt{\beta_w} \\ \text{in which:} \\ &= \text{distance between shear centers of the flanges h, '= 289.3 mm} \\ &= 0.566h_s\sqrt{(A/J)} = 0.566\cdot289.3\sqrt{(5380/19.9.10^4)} = 26.92 \\ &= \frac{1}{\left[1 + 0.05(\lambda/x)^2\right]^{0.25}} = \frac{1}{\left[1 + 0.05(119.38/26.92)^2\right]^{0.25}} = 0.84 \\ &= \sqrt{\left[\frac{4}{1} + 0.05(\lambda/x)^2\right]^{0.25}} = \left[\frac{4\cdot628\cdot10^3 \cdot 0.927}{(5380^2 \cdot 289.3^2)}\right]^{0.25} = 0.84 \\ &= \sqrt{\left[\frac{4}{2}h_s^2\right]^{0.25}} = \left[\frac{4\cdot628\cdot10^3 \cdot 0.927}{(5380^2 \cdot 289.3^2)}\right]^{0.25} = 0.88 \\ &= \text{for class 1: } \beta_w = 1 \\ &=$$



Buckling resistance moment

```
- for class 1 :
```

 $M_{b} = p_{b} \cdot S_{v} = 146.15 \cdot 628 \cdot 10^{3} = 91.78 \text{ kNm}$ 

### Bending

#### About y-Axis (Major Axis)

Moment capacity

 $M_{by} = p_y \cdot Z_y = 275 \cdot 557 \cdot 10^3 = 153.175 \text{ kNm}$ 

#### About z-Axis (Minor Axis)

Moment capacity

 $M_{bz} = p_v \cdot Z_z = 275 \cdot 80.5 \cdot 10^3 = 22.137 \text{ kNm}$ 

# Equivalent uniform moment factors and interaction factors

### Bending about y-axis (major axis)

Equivalent uniform moment factor according to table 26

 $m_y = 0.2 + \frac{0.1M_2 + 0.6M_3 + 0.1M_4}{M_{max}} = 0.2 + \frac{0.1 \cdot 7.5 + 0.6 \cdot 10 + 0.1 \cdot 7.5}{10} = 0.95$ 

#### Bending about z-axis (minor axis)

Equivalent uniform moment factor according to table 26

$$m_z = 0.2 + \frac{0.1M_2 + 0.6M_3 + 0.1M_4}{M_{max}} = 0.2 + \frac{0.1 \cdot 3.75 + 0.6 \cdot 7.5 + 0.1 \cdot 3.75}{7.5} = 0.9$$

#### Lateral-torsional buckling

Equivalent uniform moment factor according to table 18

$$m_{LT} = 0.2 + \frac{0.15M_2 + 0.5M_3 + 0.15M_4}{M_{max}} = 0.2 + \frac{0.15 \cdot 7.5 + 0.5 \cdot 10 + 0.15 \cdot 7.5}{10} = 0.925$$

### Member buckling resistance

The buckling resistance of a member may be verified by checking that the following relationships are both satisfied:

#### • Check according to 4.8.3.3.1a

 $P_c$  – is the smaller of  $P_{cy}$  and  $P_{cz}$  - for our case  $P_{cz}$  .



#### Design in RF-STEEL BS - check no.341

Axial Compression	Fc	300.00	kN		
Design Strength	p <sub>v</sub>	275.000	N/mm <sup>2</sup>		
Gross Area	A <sub>q</sub>	5380.000	mm <sup>2</sup>		
Modulus of Elasticity	E	205000.000	N/mm <sup>2</sup>		
Nominal Effective Length	KLz	4000.000	mm		
Radius of Gyration	r <sub>z</sub>	33.506	mm		
Slenderness	λ <sub>z</sub>	119.380			4.7.2
Limiting Slenderness	λο	17.155			C.2
Strut Curve	SCz	b			Table 23
Robertson Constant	az	3.500			C.2
Perry Factor	ηz	0.358			C.2
Factor	φ <sub>z</sub>	233.881	N/mm <sup>2</sup>		C.1
Euler Buckling Stress	p <sub>Ez</sub>	141.967	N/mm <sup>2</sup>		C.1
Compressive Strength	p <sub>cz</sub>	108.744	N/mm <sup>2</sup>		C.1
Compression Resistance	P <sub>cz</sub>	585.04	kN		4.7.4 / 4.7.5
Compressive Design Ratio	$\eta_{nz}$	0.51			4.8.3.3
Maximum Moment	$M_{y,max}$	10.00	kNm		
Elastic Section Modulus	Zy	557000.000	mm³		
Moment Capacity	M <sub>cy</sub>	153.18	kNm		4.2.5.2
Structure Type	Туре	Non-sway			4.8.3.3.4
Equivalent Uniform Moment Factor	m <sub>y</sub>	0.950			
Maximum Moment	$M_{z,max}$	7.50	kNm		
Elastic Section Modulus	Zz	80500.000	mm³		
Moment Capacity	M <sub>cz</sub>	22.14	kNm		4.2.5.2
Structure Type	Туре	Non-sway			4.8.3.3.4
Equivalent Uniform Moment Factor	m <sub>z</sub>	0.900			
Bending Design Ratio	$\eta_{mz}$	0.07			4.8.3.3.1
Bending Design Ratio	$\eta_{mz}$	0.34			4.8.3.3.1
Design Ratio	η	0.88		< 1	4.8.3.3.1

<sup>•</sup> Check according to 4.8.3.3.1b

 $\begin{aligned} & \frac{F_c}{P_{cz}} + \frac{m_{LT} \ M_{LT}}{M_b} + \frac{m_z \ M_z}{M_{bz}} \leq 1 \\ & \frac{300}{585.04} + \frac{0.925 \cdot 10}{91.78} + \frac{0.9 \cdot 7.5}{22.137} \leq 1 \end{aligned}$ 

 $0.51\!+\!0.11\!+\!0.34\leq \!1$ 

- Satisfied



#### Design in RF-STEEL BS – check no.351

Axial Compression	F	300.00	kN		
Design Strength	p <sub>y</sub>	275.000	N/mm <sup>2</sup>		
Gross Area	A <sub>g</sub>	5380.000	mm <sup>2</sup>		
Modulus of Elasticity	E	205000.000	N/mm <sup>2</sup>		
Nominal Effective Length	KL,	4000.000	mm		
Radius of Gyration	r <sub>z</sub>	33.506	mm		
Slenderness	$\lambda_z$	119.380			4.7.2
Limiting Slenderness	λο	17.155			C.2
Strut Curve	SCz	b			Table 23
Robertson Constant	az	3.500			C.2
Perry Factor	η <sub>z</sub>	0.358			C.2
Factor	φ <sub>z</sub>	233.881	N/mm <sup>2</sup>		C.1
Euler Buckling Stress	p <sub>Ez</sub>	141.967	N/mm <sup>2</sup>		C.1
Compressive Strength	р <sub>сz</sub>	108.744	N/mm <sup>2</sup>		C.1
Compression Resistance	P <sub>cz</sub>	585.04	kN		4.7.4 / 4.7.5
Compressive Design Ratio	η	0.51			4.8.3.3
Maximum Moment	M <sub>LT,y,max</sub>	10.00	kNm		
Effective Length	L <sub>E</sub>	4000.000	mm		4.3.5
Slenderness	λ	119.380			4.3.6.7
Limiting Slenderness	$\lambda_{LO}$	34.310			B.2.2
Equivalent Slenderness	$\lambda_{LT}$	88.692		$>\lambda_{L0}$	
Robertson Constant	a <sub>LT</sub>	7.000			B.2.1
Perry Factor	η <sub>ιτ</sub>	0.381			B.2.1
Factor	$\phi_{LT}$	315.062	N/mm <sup>2</sup>		B.2.1
Euler Buckling Stress	p <sub>e,lt</sub>	257.211	N/mm <sup>2</sup>		B.2.1
Bending Strength	p <sub>b</sub>	146.151	N/mm <sup>2</sup>		4.3.6.5
Plastic Section Modulus	Sy	628000.000	mm <sup>3</sup>		
Elastic Section Modulus	Zy	557000.000	mm³		
Buckling Resistance Moment	M <sub>b,y</sub>	91.78	kNm		4.3.6.4
Moment Factor	m <sub>LT</sub>	0.925			4.3.6.6
LTB Design Ratio	η <sub>m,LT</sub>	0.11			4.8.3.3.1
Maximum Moment	$M_{z,max}$	7.50	kNm		
Elastic Section Modulus	Zz	80500.000	mm³		
Moment Capacity	M <sub>cz</sub>	22.14	kNm		4.2.5.2
Structure Type	Туре	Non-sway			4.8.3.3.4
Equivalent Uniform Moment Factor	m <sub>z</sub>	0.900			
Bending Design Ratio	η <sub>mz</sub>	0.34			4.8.3.3.1
Design Ratio	η	0.92		< 1	4.8.3.3.1



# **A** Literature

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