Dlubal

Version
August 2014

Add-on Module

RF-TIMBER AWC

Design of Timber Members
According to ANSI/AWC NDS-2012

Program Description

Am Zellweg 2 D-93464 Tiefenbach

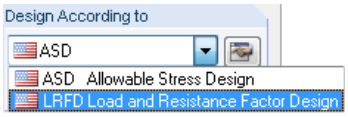
Tel.: +49 9673 9203-0
Fax: +49 9673 9203-51
E-mail: info@dlubal.com
Web: www.dlubal.com

Contents

	Contents	Page
1.	**Introduction**	**4**
1.1	Add-on Module RF-TIMBER AWC	4
1.2	RF-TIMBER AWC - Team	5
1.3	Using the Manual	6
1.4	Open the Add-on Module RF-TIMBER AWC	6
2.	**Input Data**	**8**
2.1	General Data	8
2.1.1	Ultimate Limit State	10
2.1.2	Serviceability Limit State	11
2.1.3	Fire Resistance	12
2.1.4	Standard	12
2.2	Materials	16
2.3	Cross-Sections	18
2.4	Load Duration	23
2.5	In-Service Conditions - Members	24
2.6	In-Service Conditions - Set of Members	25
2.7	Effective Lengths - Members	26
2.8	Effective Lengths - Sets of Members	30
2.9	Additional Design Parameters	31
2.10	Curved Members	32
2.11	Serviceability Data	33
2.12	Fire Resistance - Members	34
2.13	Fire Resistance - Sets of Members	35
2.14	Tapered Members	36
3.	**Calculation**	**38**
3.1	Detail Settings	38
3.1.1	Resistance	38
3.1.2	Stability	39
3.1.3	Serviceability	40
3.1.4	Fire Resistance	41
3.1.5	Other	42
3.2	Start Calculation	43
4.	**Results**	**44**
4.1	Design by Load Case	45
4.2	Design by Cross-Section	46
4.3	Design by Set of Members	47
4.4	Design by Member	48
4.5	Design by x-Location	48
4.6	Governing Internal Forces by Member	49
4.7	Governing Internal Forces by Set of Members	50
4.8	Member Slendernesses	51
4.9	Parts List by Member	52
4.10	Parts List by Set of Members	53
5.	**Evaluation of Results**	**54**
5.1	Results in the RFEM Model	55
5.2	Result Diagrams	57
5.3	Filter for Results	58
6.	**Printout**	**60**
6.1	Printout Report	60
6.2	Graphic Printout	60
7.	**General Functions**	**62**
7.1	Design Cases	62
7.2	Cross-Section Optimization	64
7.3	Units and Decimal Places	66
7.4	Data Transfer	67
7.4.1	Material Export to RFEM	67
7.4.2	Export of Effective Length to RFEM	67
7.4.3	Export of Results	67
8.	**Examples**	**69**
8.1	Beam Column (LRFD Solution)	69
8.1.1	System and Loads	69
8.1.2	Calculation with RFEM	69
8.1.3	Design with RF-TIMBER AWC	70
8.2	Glued Laminated Beam (ASD Solution)	78
8.2.1	System and Loads	78
8.2.2	Calculation with RFEM	78
8.2.3	Design with RF-TIMBER AWC	80
8.2.3.1	Ultimate Limit State Design	80
8.2.3.2	Serviceability Limit State Design	86
8.3	Single Tapered Beam	89
8.3.1	System and Loads	89
8.3.2	Calculation with RFEM	89
8.3.3	Design with RF-TIMBER AWC	90
8.4	Curved Beam (LRFD Solution)	97
8.4.1	System and Loads	97
8.4.2	Calculation with RFEM	97
8.4.3	Design with RF-TIMBER AWC	98
A	**Literature**	**105**
B	**Index**	**106**

1. Introduction

1.1 Add-on Module RF-TIMBER AWC



The National Design Specification for Wood Construction (ANSI/AWC NDS-2012) incorporates design provisions for both allowable stress design (ASD) and load and resistance factor design (LRFD). This specification is adopted in all model building codes in the United States and is used to design wood structures worldwide. With the RFEM add-on module RF-TIMBER AWC from the company DLUBAL all users obtain a powerful tool for the design of timber structures modeled with member elements according to this standard.

RF-TIMBER AWC performs all cross-section resistance designs, stability analyses, and deformation analyses provided by the standard. The stability analysis is carried out according to the equivalent member method or the second-order analysis. When the equivalent member method is applied, the program considers stability factors based on effective buckling lengths and effective lengths for lateral buckling. Second order analysis requires definition of imperfections in RFEM and calculates with unit stability factors for compression with buckling. In addition to this, the fire resistance design for allowable stress design (ASD) is possible.

In timber construction, the serviceability limit state represents an important design. In this connection, chosen load cases, load combinations, and result combinations can be checked for limit deflection. The conservative limit deformation is preset, but can be modified, if necessary. In addition to this, it is possible to specify reference lengths and precambers that will be considered accordingly in the design.

If necessary, you can optimize standardized or parametric cross-sections and export them to RFEM. Separate design cases allow for a separate design of large systems or analysis of variants.

RF-TIMBER AWC is one of the add-on modules integrated in the RFEM environment. Thus, the design-relevant input data is preset when you open the module. Subsequent to the design, you can use the graphical RFEM user interface to evaluate the results. Last but not least, you can document the checks from the analysis of internal forces to the design in the global printout report.

We hope you will enjoy working with RF-TIMBER AWC.

Your DLUBAL Team

1.2 RF-TIMBER AWC - Team

The following people were involved in the development of RF-TIMBER AWC:

Program coordination

Dipl.-Ing. Georg Dlubal
Dipl.-Ing. (FH) Bastian Kuhn
Ing. Ondřej Švorc

Programming

Ing. Tomáš Drtina
Ing. Jiří Patrák
Dipl.-Ing. Georg Dlubal

Cross-section and material database

Ing. Jan Rybín, Ph.D.
Ing. Jiří Kubíček
Mgr. Petr Oulehle

Program design, dialog figures, icons

Dipl.-Ing. Georg Dlubal
Ing. Jan Miléř
MgA. Robert Kolouch

Program supervision

Ing. Jiří Hanzálek
Ing. Ondřej Švorc
Dipl.-Ing. (FH) Gerhard Rehm
Ing. Myroslava Petronyuk

Localization, manual

Ing. Fabio Borriello
Mgr. Ing. Hana Macková
Ing. Dmitry Bystrov
Ing. Téc. José Martínez Hernández
Eng.º Rafael Duarte
Dipl.-Ü. Gundel Pietzcker
Ing. Lara Caballero Freyer
Mgr. Jagoda Podgórna
Ing. Alessandra Grosso, Ph.D.
BSc Eng Chelsea Prokop
Ing. Ladislav Kábrt
Dipl.-Ing. Jing Sun
Ing. Aleksandra Kociołek
Ing. Marcela Svitáková
Eng.º Nilton Lopes Fernandes
Dipl.-Ing. (FH) Robert Vogl

Technical support and quality management

M.Eng. Cosme Asseya
Dipl.-Ing. (FH) Bastian Kuhn
Dipl.-Ing. (BA) Markus Baumgärtel
Dipl.-Ing. (FH) Ulrich Lex
Dipl.-Ing. Moritz Bertram
Dipl.-Ing. (BA) Sandy Matula
M.Sc. Sonja von Bloh
M.Eng. Dipl.-Ing. (BA) Andreas Niemeier
Dipl.-Ing. (FH) Steffen Clauß
Dipl.-Ing. (FH) Gerhard Rehm
Dipl.-Ing. Frank Faulstich
M.Eng. Dipl.-Ing. (FH) Walter Rustler
Dipl.-Ing. (FH) René Flori
M.Sc. Dipl.-Ing. (FH) Frank Sonntag
Dipl.-Ing. (FH) Stefan Frenzel
Dipl.-Ing. (FH) Christian Stautner
Dipl.-Ing. (FH) Walter Fröhlich
Dipl.-Ing. (FH) Lukas Sühnel
Dipl.-Ing. (FH) Paul Kieloch
Dipl.-Ing. (FH) Robert Vogl

1.3 Using the Manual

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

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

At the end of the manual, you find the index. However, if you still cannot find what you are looking for, please check the DLUBAL blogs at **https://www.dlubal.de/blog/en** where you can search the articles by specific terms.

1.4 Open the Add-on Module RF-TIMBER AWC

RFEM provides the following options to start the add-on module RF-TIMBER AWC.

Menu

To start the program in the RFEM menu bar, click

Add-on Modules → Design - Timber → RF-TIMBER AWC.

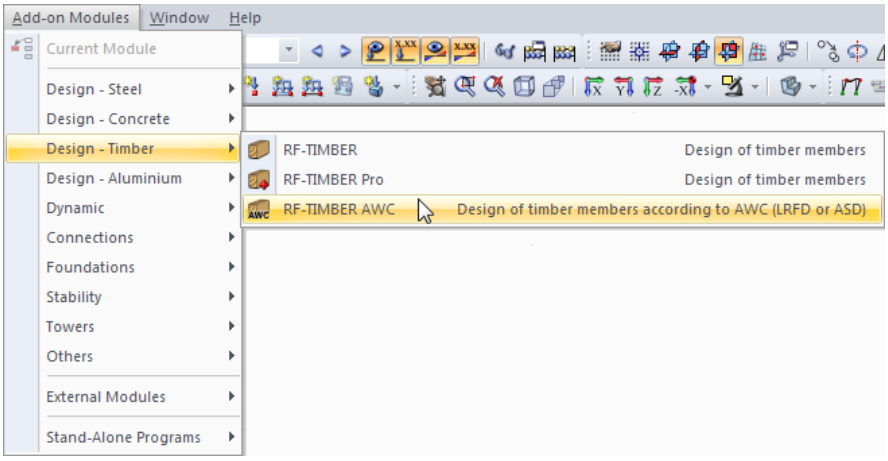


Figure 1.1: Menu: *Add-on Modules → Design - Timber → RF-TIMBER AWC*

Navigator

As an alternative, you can start the add-on module in the *Data* navigator by clicking

Add-on Modules → RF-TIMBER AWC.

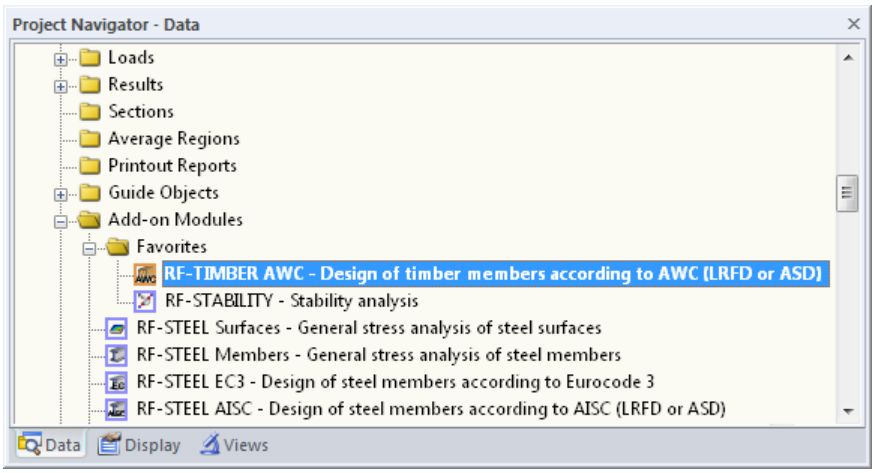
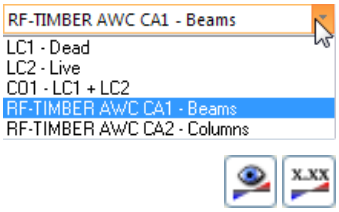


Figure 1.2: Data navigator: *Add-on Modules → RF-TIMBER AWC*

Panel



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

Set the relevant RF-TIMBER AWC design case in the load case list of the RFEM toolbar. Then click the [Show results] button to graphically display the design criterion on the members.

When the results display is activated, the panel is available, too. Now you can click the button [RF-TIMBER AWC] in the panel to open the module.

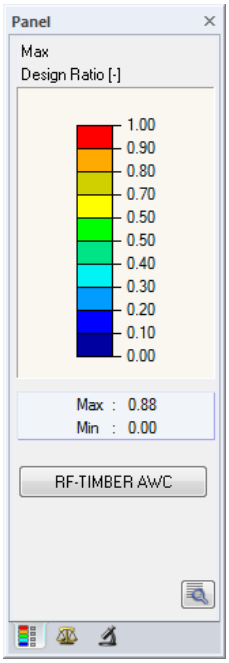


Figure 1.3: Panel button [RF-TIMBER AWC]

2. Input Data

When you have started the add-on module, a new window opens. In this window a Navigator is displayed on the left, managing the available windows that can be currently selected. The drop-down list above the navigator contains the design cases (see Chapter 7.1, page 62).

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

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

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

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

2.1 General Data

In the 1.1 *General Data* window, you select the members, sets of members, and actions that you want to design. The tabs are managing the load cases, load and result combinations for the different designs.

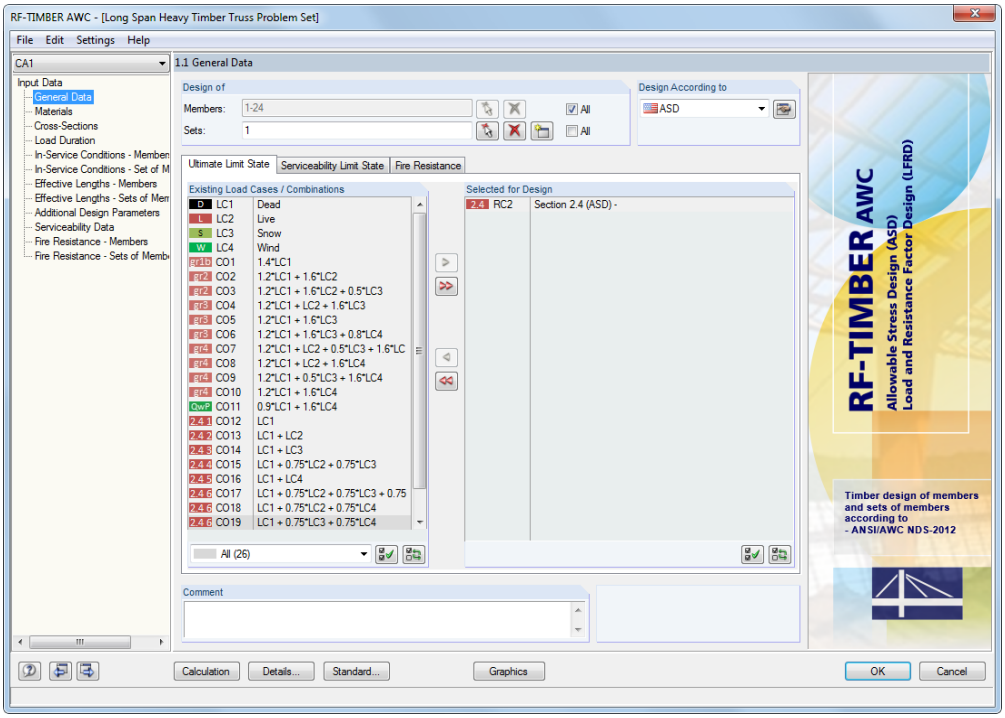


Figure 2.1: Window 1.1 *General Data*

Design of

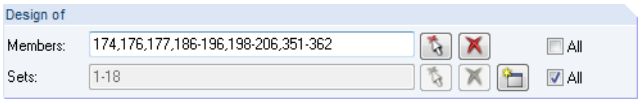


Figure 2.2: Design of members and sets of members

The design can be carried out for *Members* as well as for *Sets of Members*. If you want to design only selected objects, clear the *All* check box. Then you can access the text boxes to enter the numbers of the relevant members or sets of members. The list of the numbers preset in the field can be cleared by clicking the [Delete] button. Alternatively, you can select the objects graphically in the RFEM work window after clicking [↖].

When you design a set of members, the program determines the extreme values of the analyses of all members contained in the set of members and takes into account the boundary conditions of connected members for the stability analysis. The results are shown in the results windows 2.3 *Designs by Set of Members*, 3.2 *Governing Internal Forces by Set of Members*, and 4.2 *Parts List by Set of Members*.

Click [New] to create a new set of members. The dialog box that you already know from RFEM appears where you can specify the parameters of set of members.

Design according to

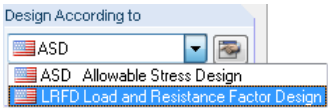


Figure 2.3: Design according to ASD or LRFD

The options of the list box control whether the analysis is carried out according to the provisions of the *Allowable Stress Design* (ASD) or the *Load and Resistance Factor Design* (LRFD).

Comment

Figure 2.4: User-defined comment

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

2.1.1 Ultimate Limit State

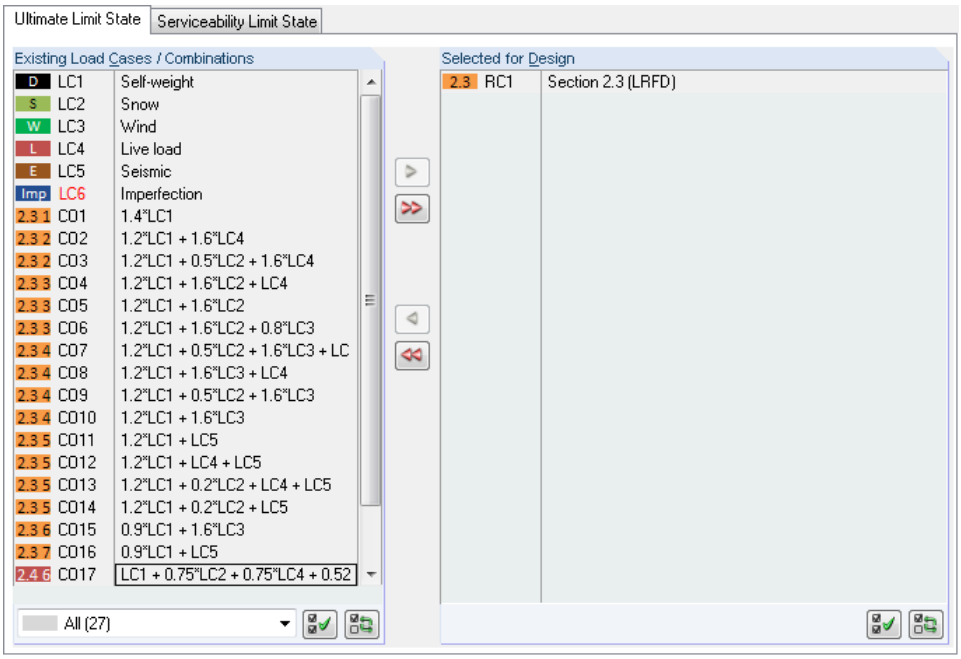


Figure 2.5: Window 1.1 *General Data*, tab *Ultimate Limit State*

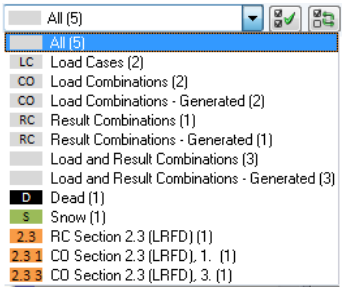
Existing Load Cases and Combinations

This column lists all load cases, load combinations, and result combinations created in RFEM.

To transfer selected entries to the *Selected for Design* list on the right, click [▶]. Alternatively, you can double-click the items. To transfer the complete list to the right, click [▶▶].

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

Load cases highlighted in red, like LC 6 in Figure 2.5, cannot be designed: This happens when the load cases are defined without any load data or the load cases contain only imperfections. When you transfer the load cases, a corresponding warning appears.



At the end of the list, several filter options are available. They will help you assign the entries sorted by load case, load combination, or action category. The buttons have the following functions:

	Selects all load cases in the list
	Inverts the selection of load cases

Table 2.1: Buttons in the tab *Ultimate Limit State*

Selected for Design

The column on the right lists the load cases, load combinations, and result combinations selected for design. To remove selected entries from the list, click [◀] or double-click the entries. To transfer the entire list to the left, click [◀◀].

The design of an enveloping max/min result combination is performed faster than the design of all contained load cases and load combinations.

However, the analysis of a result combination has also disadvantages: First, the influence of the contained actions is difficult to discern. Second, for the determination of the volume factor C_V for structural glued laminated timber, the envelope of the moment distributions is analyzed.

From that, the most unfavorable distribution (max or min) is applied. However, this distribution only rarely reflects the moment distribution in the individual load combinations. Thus, in the case of RC design, more unfavorable values of the factor C_v are to be expected, leading to higher ratios.

Result combinations should be selected for design only for dynamic combinations. For "usual" combinations, load combinations are recommended.

2.1.2 Serviceability Limit State

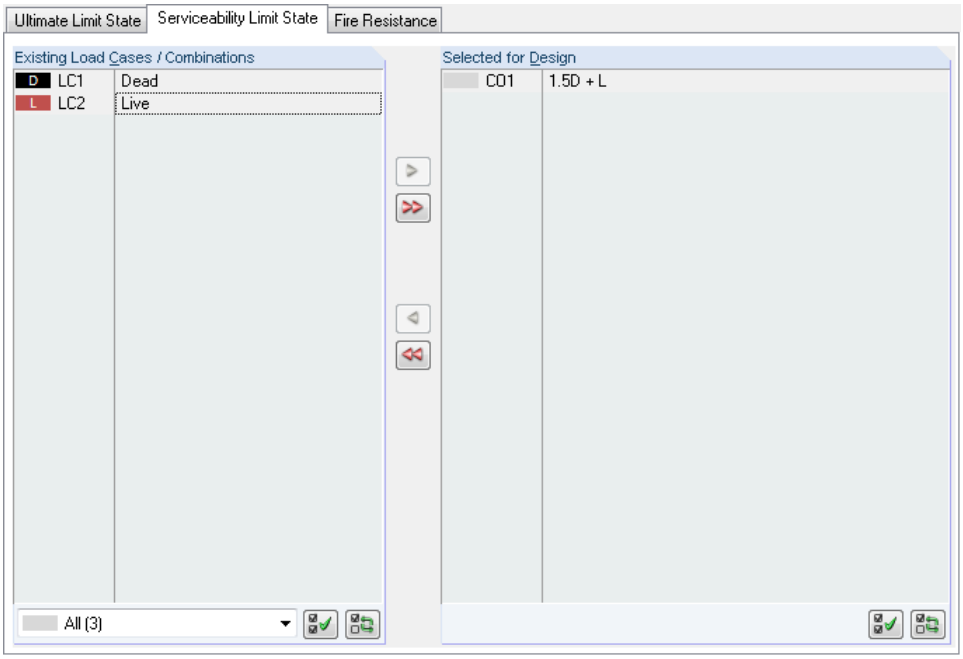


Figure 2.6: Window 1.1 *General Data*, tab *Serviceability Limit State*

Existing Load Cases and Combinations

This section lists all load cases, load combinations, and result combinations created in RFEM.

Selected for Design

Load cases, load combinations, and result combinations can be added or removed (see Chapter 2.1.1).

The limit value of the deformation is controlled by the settings in the *Details* dialog box (see Figure 3.3, page 40) which you can call up by clicking the [Details] button.

In the 1.10 *Serviceability Data* window, the reference lengths decisive for the deformation check are managed (see Chapter 2.11, page 33).

2.1.3 Fire Resistance

This tab is only available when the ASD design method has been set.

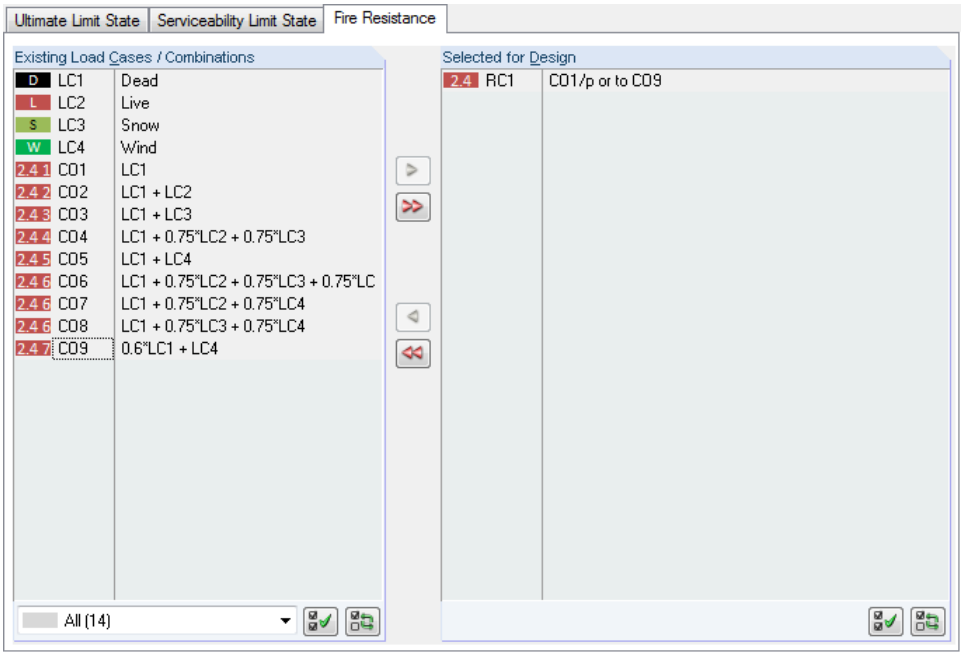
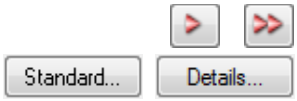


Figure 2.7: Window 1.1 *General Data*, tab *Fire Resistance*

Existing Load Cases and Combinations

All load cases, load combinations, and result combinations created in RFEM are listed here.

Selected for Design



Load cases, load and result combinations can be added or removed (see Chapter 2.1.1).

The fire resistance design is performed by means of a reduced cross-section. The general specifications for the fire resistance design are managed in the dialog boxes *Standard* (see Figure 2.9, page 13) and *Details*, tab *Fire Resistance* (see Figure 3.4, page 41).

2.1.4 Standard

The drop-down lists in the 1.1 *General Data* window allow you to select the method of design whose parameters are to be applied to the design.

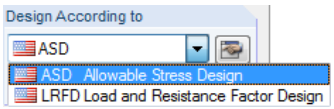


Figure 2.8: Design method

To check and, if necessary, adjust the preset parameters, click [Edit] (see the following figure).

Alternatively you can use the [Standard] button in all input windows in order to open the *Standard* dialog box consisting of three tabs. The content of the dialog box depends on the selected design method.

General

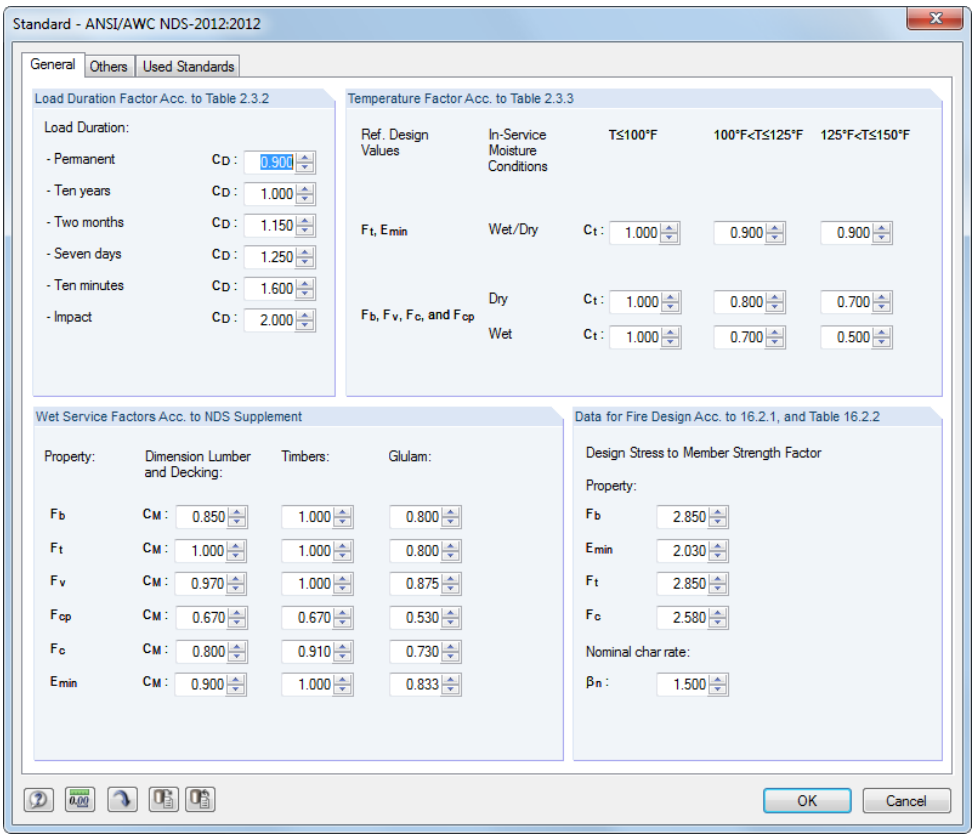


Figure 2.9: Dialog box *Standard*, tab *General* for **ASD** design method

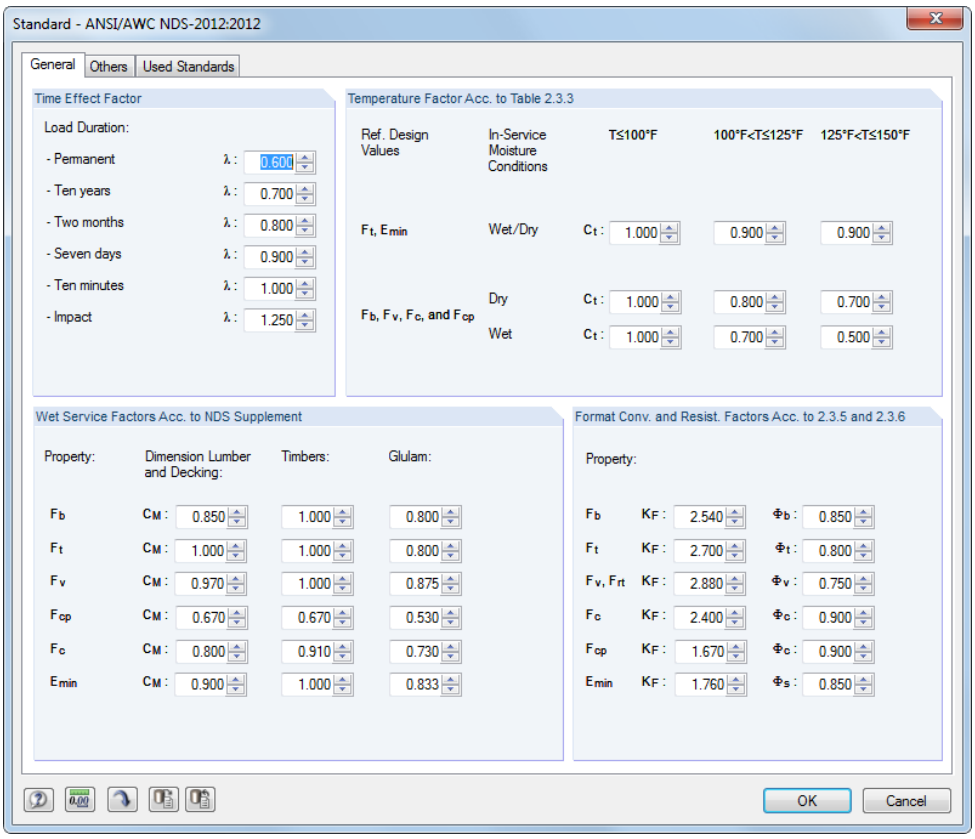


Figure 2.10: Dialog box *Standard*, tab *General* for **LRFD** design method

In the dialog box sections, you can check or, if necessary, modify, the *Wet Service Factors* and the *Temperature Factor* (prescribed for both ASD and LRFD method), the *Load Duration* or *Time Effect Factor* (different for ASD and LRFD method), and the *Format Conversion and Resistance Factors* (LRFD only).

The *Data for Fire Design* section manages the parameters *Design Stress to Member Strength Factor* and *Nominal charring rate* β_n. The fire design is applied only for the ASD design method.

The buttons in the *Standard* dialog box have the following functions:

Button	Function
	Resets the program's default settings
	Imports user-defined standard settings
	Saves the current settings as default
	Deletes a user-defined Standard

Table 2.2: Buttons in dialog box *Standard*

Others

In the second tab of the *Standard* dialog box, you find several factors significant for the design. These factors are prescribed for both ASD and LRFD methods and can be also modified, if necessary.

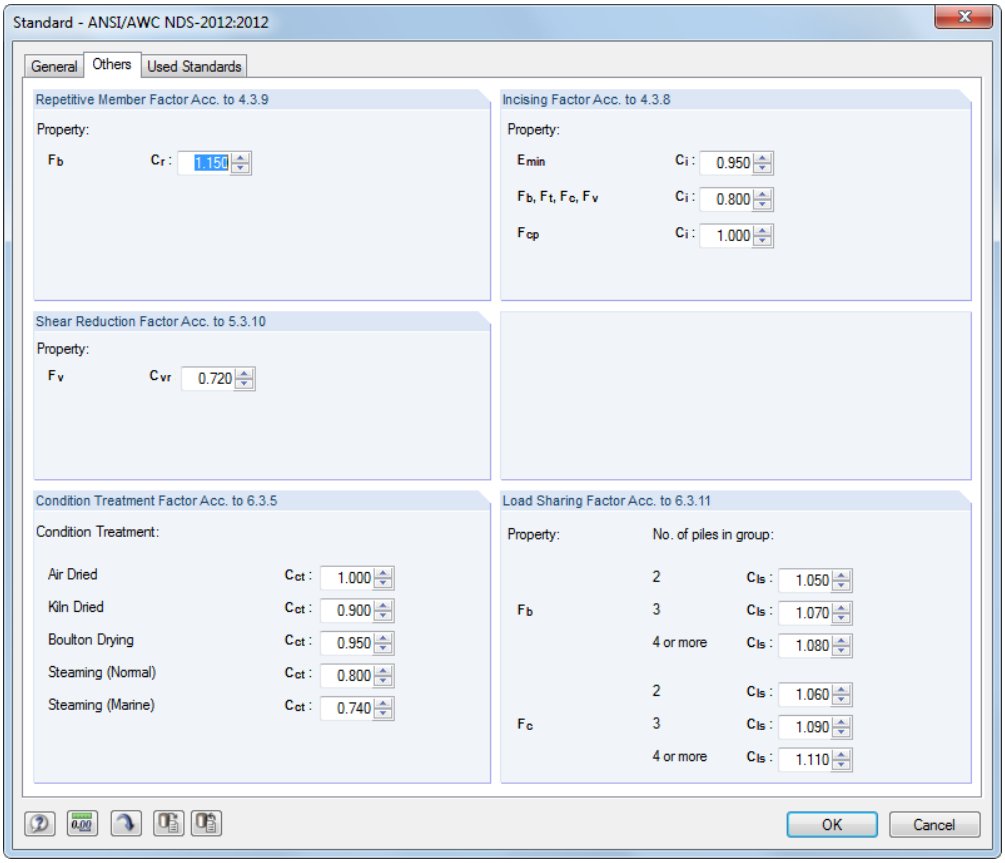


Figure 2.11: Dialog box *Standard*, tab *Others*

Used Standards

The third tab of the *Standard Settings* dialog box informs you about the Standards according to which the design will be performed.

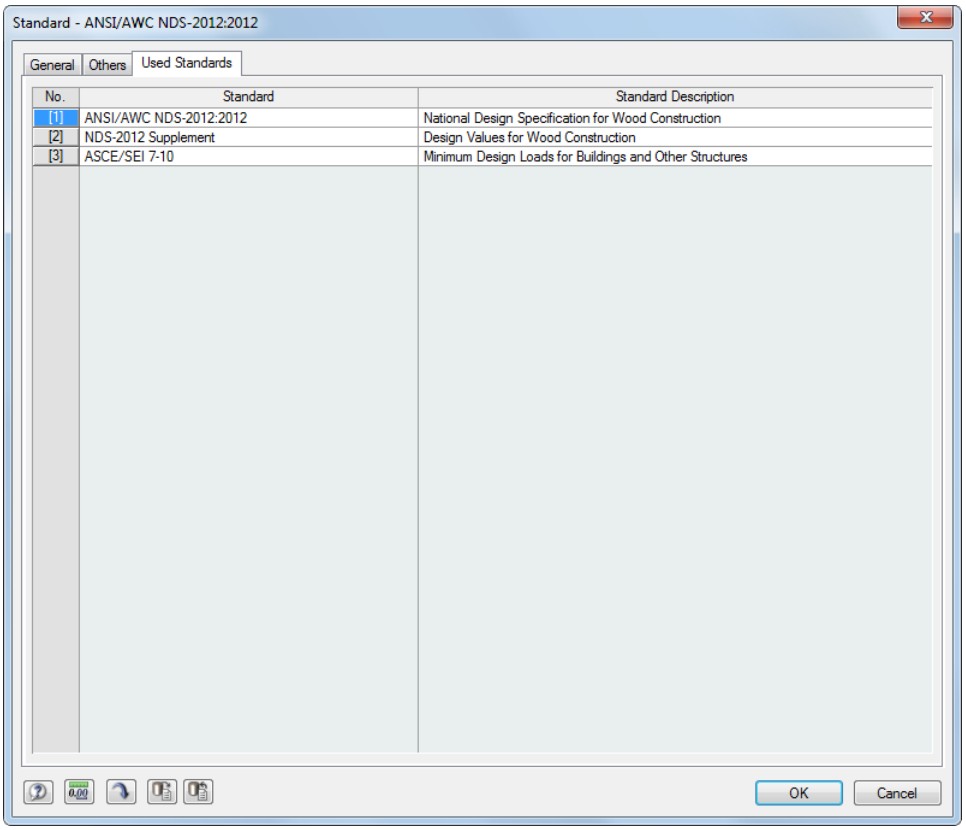


Figure 2.12: Dialog box *Standard*, tab *Used Standards*

2.2 Materials

The window consists of two parts. In the upper part, all materials created in RFEM are listed. In the *Material Properties* section, the properties of the current material, that is, the table row currently selected in the upper section, are displayed.

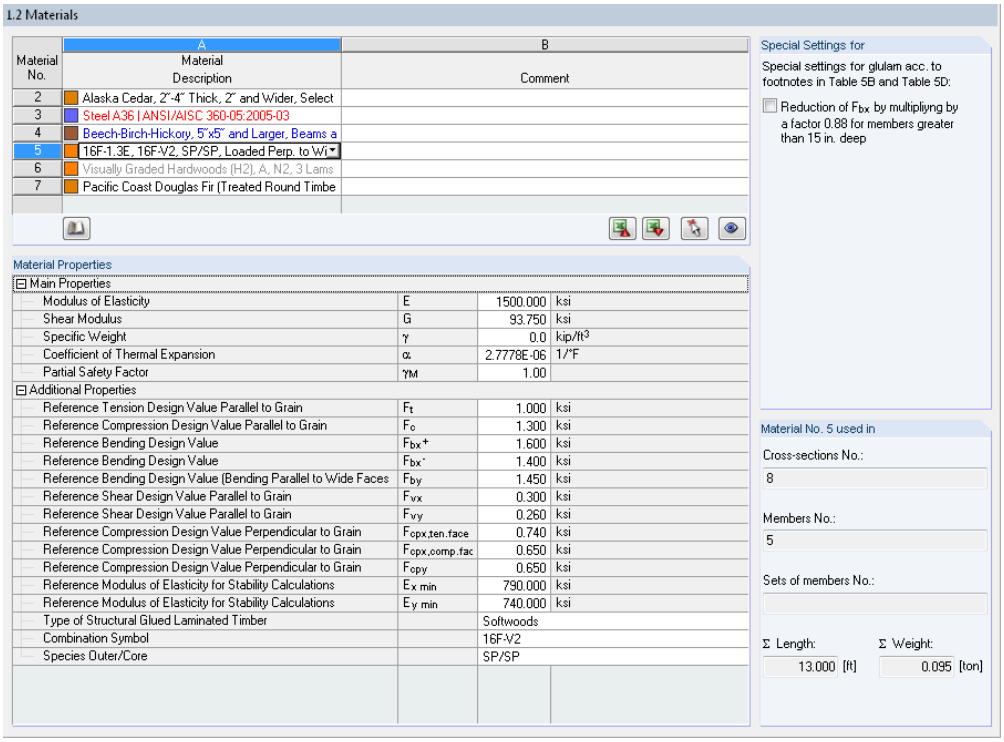


Figure 2.13: Window 1.2 *Materials*

Materials that will not be used in the design are dimmed. Materials that are not allowed are highlighted in red. Modified materials are displayed in blue.

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

To adjust the units and decimal places of material properties and stresses, select from the module's menu **Settings** → **Units and Decimal Places** (see Chapter 7.3, page 66).

Material Description

The materials defined in RFEM are preset, but you can always modify them: To select the field, click the material in column A. Then click [▼] or press function key [F7] to open the material list.

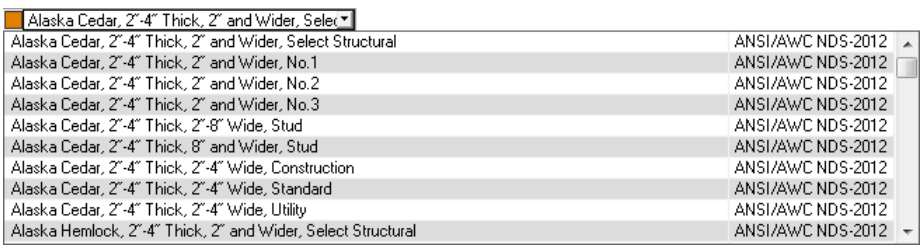


Figure 2.14: List of materials

According to the design concept of ANSI/AWC NDS-2012 [1] and its Supplement [2], the list includes only materials of the U.S. standard. Visually graded decking (i.e. material according to [2] "Table 4E") is not included in RF-TIMBER AWC.

When you have imported a material, the design relevant *Material Properties* are updated.

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

It is not possible to edit the material properties in the add-on module RF-TIMBER AWC.

Material Library

Numerous materials are already available in the library. To open the corresponding dialog box, select menu

Edit → Material Library

or click the button shown on the left.

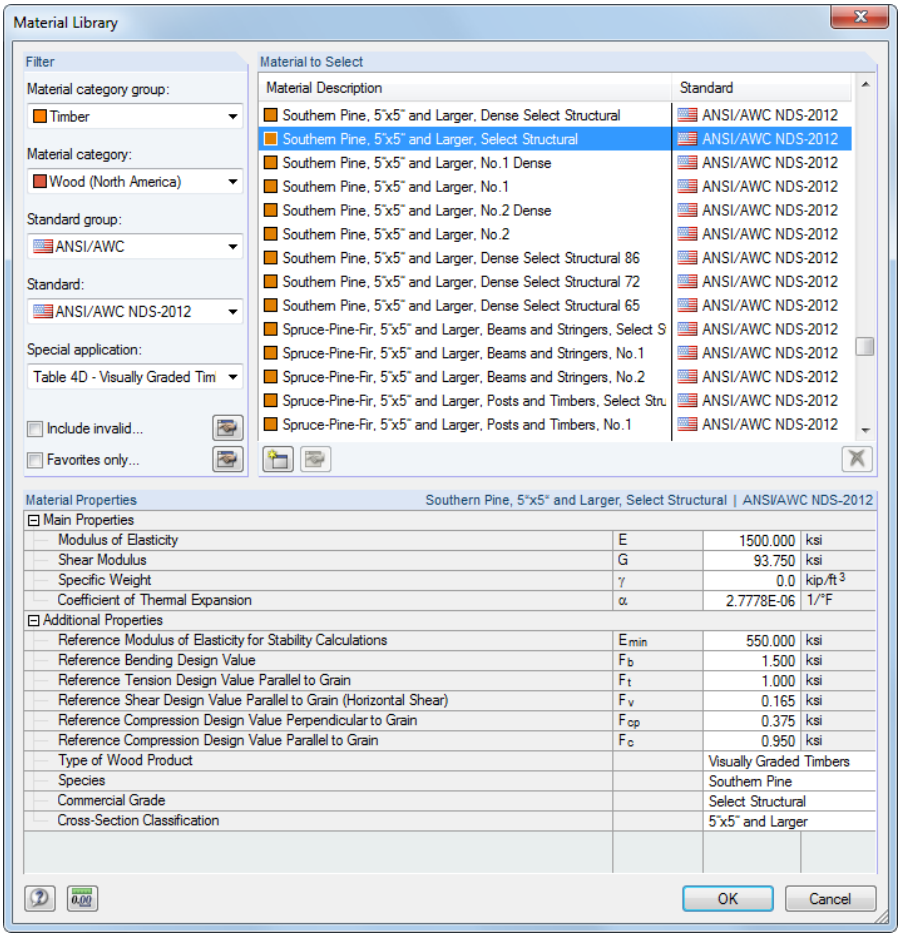
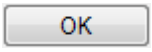


Figure 2.15: Dialog box *Material Library*

In the *Filter* section, *ANSI/AWC* is preset as Standard. Select the material quality that you want to use for the design in the *Material to Select* list. You can check the corresponding properties in the dialog section below.



Click [OK] or press [↵] to transfer the selected material to Window 1.2 of RF-TIMBER AWC.

Chapter 4.3 of the RFEM manual describes in detail how materials can be filtered, added, or rearranged.

Material Properties

The lower section of Window 1.2 contains the reference design values for bending F_b, tension parallel F_t, shear F_v, compression parallel F_c, compression perpendicular F_{cp}, as well as modulus of elasticity for stability calculations E_{min}.

The reference bending, shear and compression perpendicular design values and reference modulus of elasticity for stability calculations for structural glued laminated timber are extended for cases of bending perpendicular and parallel to wide faces of laminations and bending to F_{bx} and F_{by}. When structural laminated timber material stressed primarily in bending (i.e. material of "Table 5A" and "Table 5C" special application) is chosen, value F_{bx} is doubled for the case of positive F_{bx}^+ and negative F_{bx}^- bending. In addition, for such a softwood timber (i.e. material of "Table 5A" special application), value F_{cp} is doubled for tension $F_{cpx,ten.face}$ and compression $F_{cpx,comp.face}$ face of cross-section.

The design values of the material strengths are to be determined with the modification factors. Those factors can be modified in the *Standard Settings* dialog box (see Figure 2.9 and Figure 2.10, page 13).

Special Settings

For cross-sections greater than 15 in. deep, where structural glued laminated timber stressed primarily in axial tension or compression (i.e. material of "Table 5B" and "Table 5D" special application) is used, the reference bending design value F_{bx} can be considered to be reduced by multiplying by a factor of 0.88.

If you select this option, the program reduces the mentioned bending design value automatically.

2.3 Cross-Sections

This window manages the cross-sections used for design. You can also specify parameters for the optimization here.

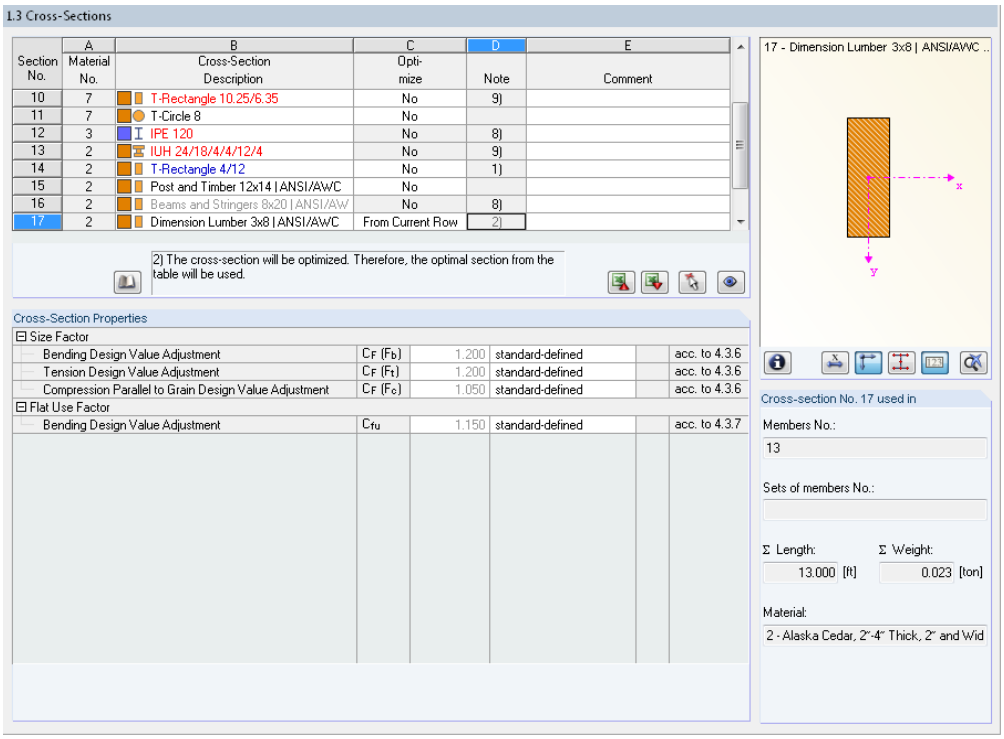


Figure 2.16: Window 1.3 *Cross-Sections*

Axis System

In RF-TIMBER AWC, the cross-sectional axis system is applied according to [1]. That system is different to the one used in RFEM: The module's axis **x** corresponds to axis *y* of RFEM, and axis **y** to axis *z* accordingly. Sometimes the axis' symbols y/x and z/y are used in RF-TIMBER AWC.

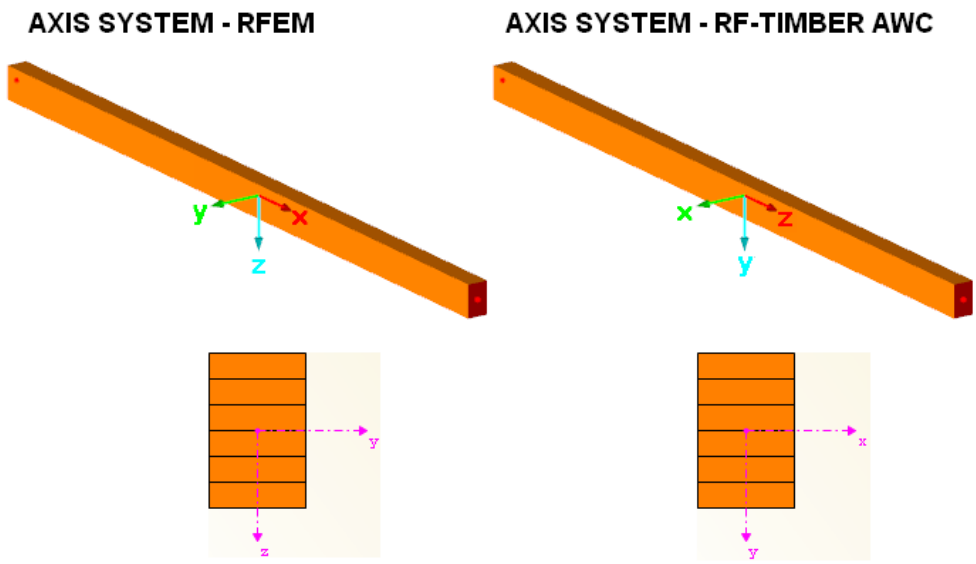
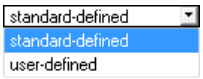


Figure 2.17: Axis systems used in RFEM and RF-TIMBER AWC

Cross-Section Description

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

The design is possible for the parametric timber rectangular and circular cross-section and for standardized timber rectangular cross-section according to ANSI/AWC NDS-2012 [1].



The table *Cross-Section Properties* below displays the size factors C_F and flat use factors C_{fu} of each cross-section. For standardized timber cross-sections (see Figure 2.19), you can define the values automatically or manually by using the [▼] button.

To modify a cross-section, click the entry in column B selecting this field. Click [Cross-section Library] or [...] in the field or press function key [F7] to open the cross-section table of the current input field (see the following two figures).

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

Chapter 4.13 of the RFEM manual describes how cross-sections can be selected from the library.

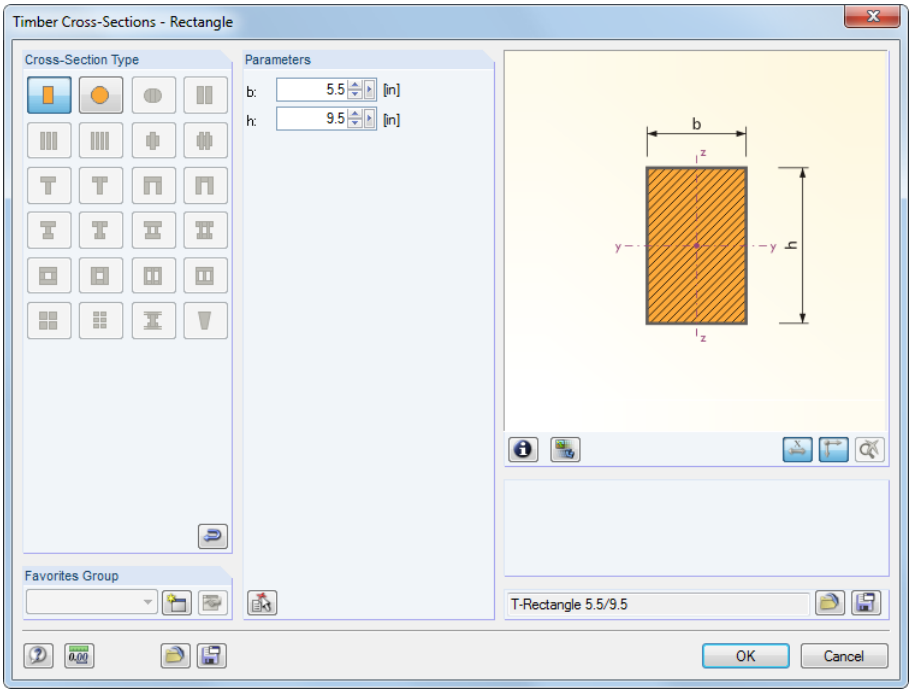


Figure 2.18: Parametric timber cross-sections of the cross-section library

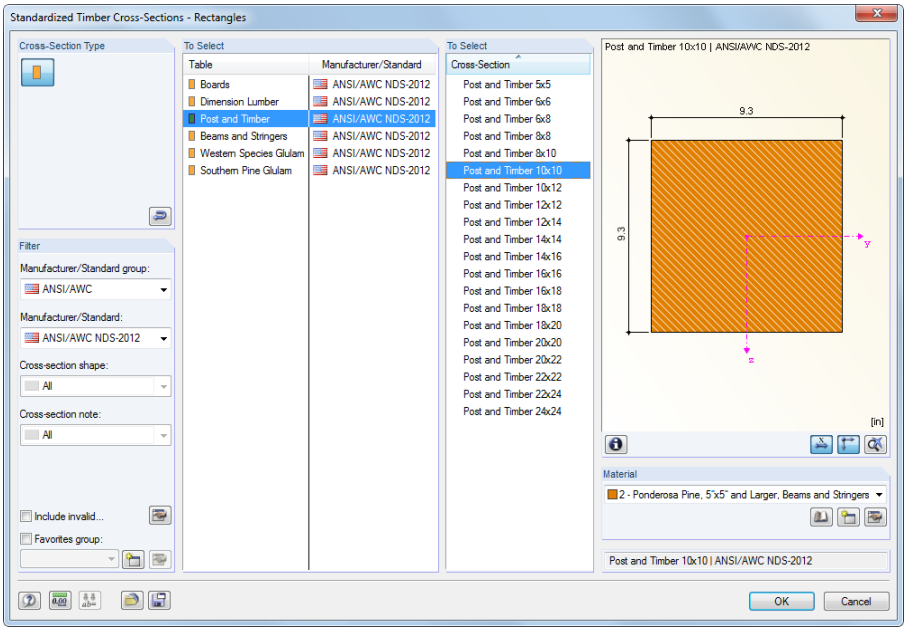
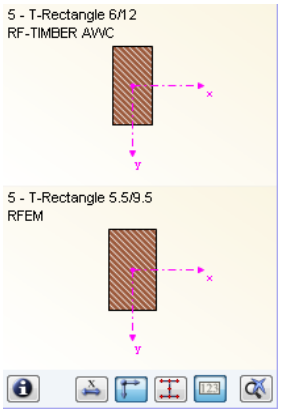


Figure 2.19: Standardized timber cross-sections of the cross-section library



The new cross-section description can be entered in the text box directly. If the data base contains an entry, RF-TIMBER AWC imports these cross-section parameters, too.

A modified cross-section will be highlighted in blue.

If cross-sections specified in RF-TIMBER AWC are different from the ones used in RFEM, both cross-sections are displayed in the graphic on the right. The designs will be performed with the internal forces of RFEM for the cross-section selected in RF-TIMBER AWC.

Max. Design Ratio

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

Optimize

You can optimize all rectangular and circular cross-sections: For the RFEM internal forces, the program searches the cross-section that comes as close as possible to a user-defined maximum utilization ratio. You can define the maximum ratio in the *Other* tab of the *Details* dialog box, (see Figure 3.5, page 42).

If you want to optimize a cross-section, open the drop-down list in column D or E. Recommendations for optimizing cross-sections can be found in Chapter 7.2 on page 63.

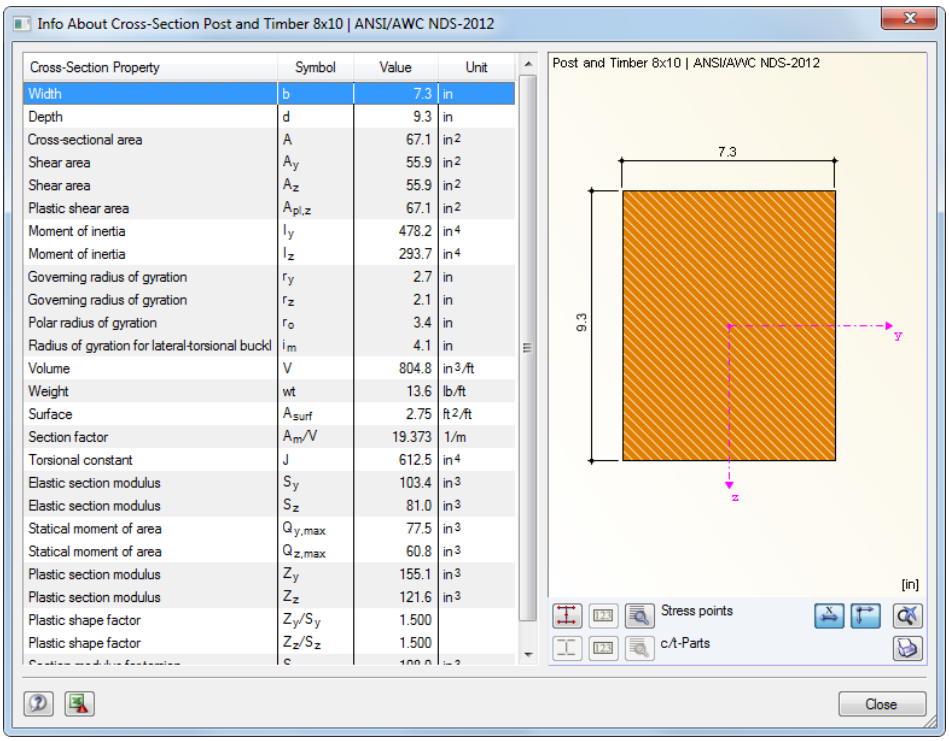
Remark

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

A warning might appear before the calculation: *Cross-section does not have a valid material!* This means that this cross-section is not allowed to be used in combination with the defined material. In RF-TIMBER AWC, it is not possible to use rectangular cross-sections with structural round timber poles and piles material (i.e. material of [2] Table 6A and Table 6B), and circular cross-sections with dimensional lumber or structural glued laminated timber (i.e. material of [2] Table 4A, Table 4B, Table 4C, Table 4D, Table 4F, Table 5A, Table 5B, Table 5C and Table 5D).

Info About Cross-Section

In the *Info About Cross-Section* dialog box, you can check the cross-section properties and stress points.



Cross-Section Property	Symbol	Value	Unit
Width	b	7.3	in
Depth	d	9.3	in
Cross-sectional area	A	67.1	in²
Shear area	A_y	55.9	in²
Shear area	A_z	55.9	in²
Plastic shear area	$A_{pl,z}$	67.1	in²
Moment of inertia	I_y	478.2	in⁴
Moment of inertia	I_z	293.7	in⁴
Governing radius of gyration	r_y	2.7	in
Governing radius of gyration	r_z	2.1	in
Polar radius of gyration	r_o	3.4	in
Radius of gyration for lateral-torsional buckl	i_m	4.1	in
Volume	V	804.8	in³/ft
Weight	wt	13.6	lb/ft
Surface	A_{surf}	2.75	ft²/ft
Section factor	A_m/V	19.373	1/m
Torsional constant	J	612.5	in⁴
Elastic section modulus	S_y	103.4	in³
Elastic section modulus	S_z	81.0	in³
Statical moment of area	$Q_{y,max}$	77.5	in³
Statical moment of area	$Q_{z,max}$	60.8	in³
Plastic section modulus	Z_y	155.1	in³
Plastic section modulus	Z_z	121.6	in³
Plastic shape factor	Z_y/S_y	1.500	
Plastic shape factor	Z_z/S_z	1.500	

Figure 2.20: Dialog box *Info About Cross-Section*

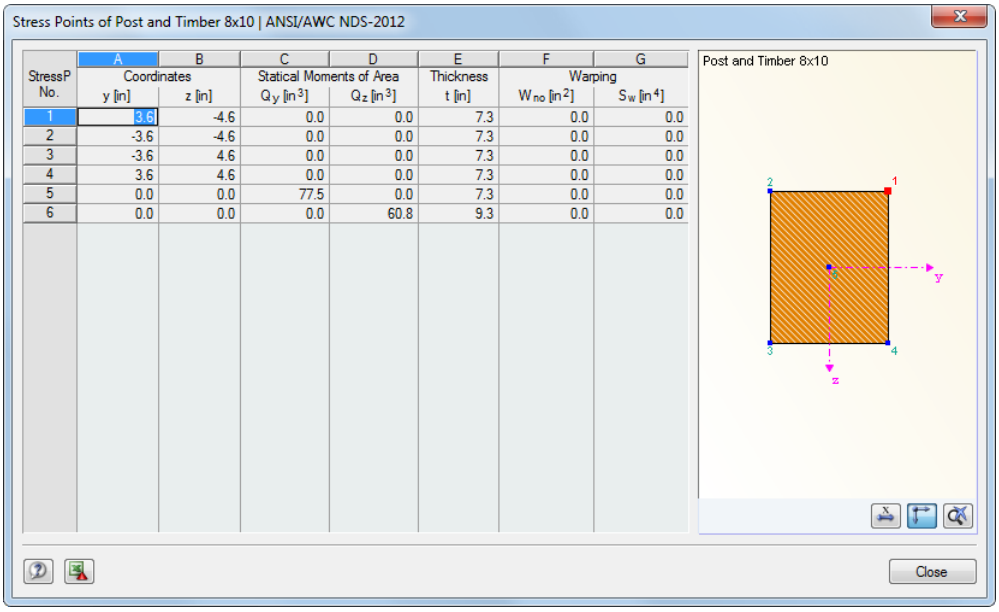
The right part of the dialog box shows the currently selected cross-section.

The buttons below the graphic have the following functions:

Button	Function
	Displays or hides the stress points
	Displays or hides the numbers of stress points
	Shows the details of the stress points (see Figure 2.21)
	Displays or hides the dimensions of the cross-section
	Displays or hides the principal axes of the cross-section
	Resets the full view of the cross-section graphic
	Prints the cross-section values and cross-section graphic

Table 2.3: Buttons of cross-section graphic

Click [Details] to call up specific information on the stress points (distances to center of gravity, statical moments, etc.).



StressP No.	A Coordinates y [in]	B Coordinates z [in]	C Statical Moments of Area Q_y [in³]	D Statical Moments of Area Q_z [in³]	E Thickness t [in]	F Warping W_{no} [in²]	G Warping S_w [in⁴]
1	3.6	-4.6	0.0	0.0	7.3	0.0	0.0
2	-3.6	-4.6	0.0	0.0	7.3	0.0	0.0
3	-3.6	4.6	0.0	0.0	7.3	0.0	0.0
4	3.6	4.6	0.0	0.0	7.3	0.0	0.0
5	0.0	0.0	77.5	0.0	7.3	0.0	0.0
6	0.0	0.0	0.0	60.8	9.3	0.0	0.0

Figure 2.21: Dialog box *Stress Points*

Member with tapered cross-section

For tapered members with different cross-sections at both member ends, the module displays the two cross-sections numbers in separate table rows, in accordance with the definition in RFEM.

RF-TIMBER AWC is also able to design tapered members if the same cross-section type is defined for the start and the end cross-section. Additional specifications are required in Window 1.14 (see Chapter 2.14, page 36).

2.4 Load Duration

In Window 1.4, you define the load duration to consider factors reflecting the different load duration for all chosen load cases, load and result combinations as well as dynamic combinations.

1.4 Load Duration

Load-ing	A Description	B Load Type	C Load Duration	D Factor λ	E Loading Condition (Radial Stress Design)	F Comments
LC1	Permanent	Dead	Permanent	0.6000	Other Types of Loading	
LC2	Live	Live	Ten Years	0.7000	Other Types of Loading	
LC3	Snow	Snow	Two Months	0.8000	Other Types of Loading	
LC4	Wind	Wind	Ten Minutes	1.0000	Wind or Earthquake Loading	
CO1	1.4*LC1	-	Permanent	0.6000	Other Types of Loading	
CO2	1.2*LC1 + 1.6*LC2	-	Ten Years	0.7000	Other Types of Loading	
CO3	1.2*LC1 + 1.6*LC2 + 0.5*LC3	-	Two Months	0.8000	Other Types of Loading	
CO4	1.2*LC1 + 0.5*LC3	-	Two Months	0.8000	Other Types of Loading	
CO5	1.2*LC1 + LC2 + 1.6*LC3	-	Two Months	0.8000	Other Types of Loading	
CO6	1.2*LC1 + 1.6*LC3	-	Two Months	0.8000	Other Types of Loading	
CO7	1.2*LC1 + 1.6*LC3 + 0.8*LC4	-	Ten Minutes	1.0000	Wind or Earthquake Loading	
CO8	1.2*LC1 + 0.8*LC4	-	Ten Minutes	1.0000	Wind or Earthquake Loading	
CO9	1.2*LC1 + LC2 + 0.5*LC3 + 1.6*LC4	-	Ten Minutes	1.0000	Wind or Earthquake Loading	
CO10	1.2*LC1 + LC2 + 1.6*LC4	-	Ten Minutes	1.0000	Wind or Earthquake Loading	
CO11	1.2*LC1 + 0.5*LC3 + 1.6*LC4	-	Ten Minutes	1.0000	Wind or Earthquake Loading	
CO12	1.2*LC1 + 1.6*LC4	-	Ten Minutes	1.0000	Wind or Earthquake Loading	
CO13	0.9*LC1 + 1.6*LC4	-	Ten Minutes	1.0000	Wind or Earthquake Loading	

Apply time effect factor λ according to: (●) Shortest load duration in a combination ( ) User-defined settings

Figure 2.22: Window 1.4 *Load Duration*

Loading

All actions selected in the 1.1 *General Data* window are listed here. For combinations, included load cases are listed, too.

Description

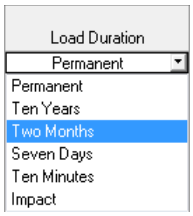
The load case descriptions make the classification easier.

Load Type

This table column shows the load cases' types of action as defined while creating them in RFEM. They are the basis for the presetting in the subsequent table column.

Load Duration

Loads and their superpositions must be assigned to the load duration for the design. The classification of actions is specified for example in [1] Table 2.3.2.



For load cases and variable result combinations, the load duration can be changed by using the list shown on the left: Click the cell in column C, thus selecting the field. The [▼] button becomes available. For load combinations and *Or* result combinations, RF-TIMBER AWC performs the classification automatically taking into account the shortest load duration action of included load cases. When the bottom-side button is switched to *User-defined settings*, load combinations and *Or* result combinations are user-changeable as well.

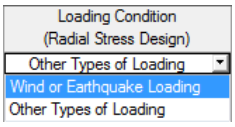
The class of the load duration is required for the determination of the load duration factor C_D in the ASD method and time effect factor λ in the LRFD method.

Factor C_D / λ

The impact of the load duration on the strength properties is taken into account by means of the load duration factor C_D (ASD) or the time effect factor λ (LRFD) (see [1] Table 2.3.2 and N3).

The factors can be checked and, if necessary, adjusted in the *Standard Settings* dialog box (see Figure 2.9 and Figure 2.10, page 13).

Loading Condition (Radial Stress Design)



In the table, column E is activated only when at least one tapered or curved member is selected for the design. In this case, the loading conditions must be assigned so that the radial tension stress, F_{rt}, can be determined (see [1] Table 5.2.8).

2.5 In-Service Conditions - Members

The determination of moisture and temperature service conditions makes it possible to assign the temperature factors C_T and wet service factors C_M to each member. The moisture service conditions can be specified individually for each material according to [2][1], the temperature conditions according to [1] Table 2.3.3.

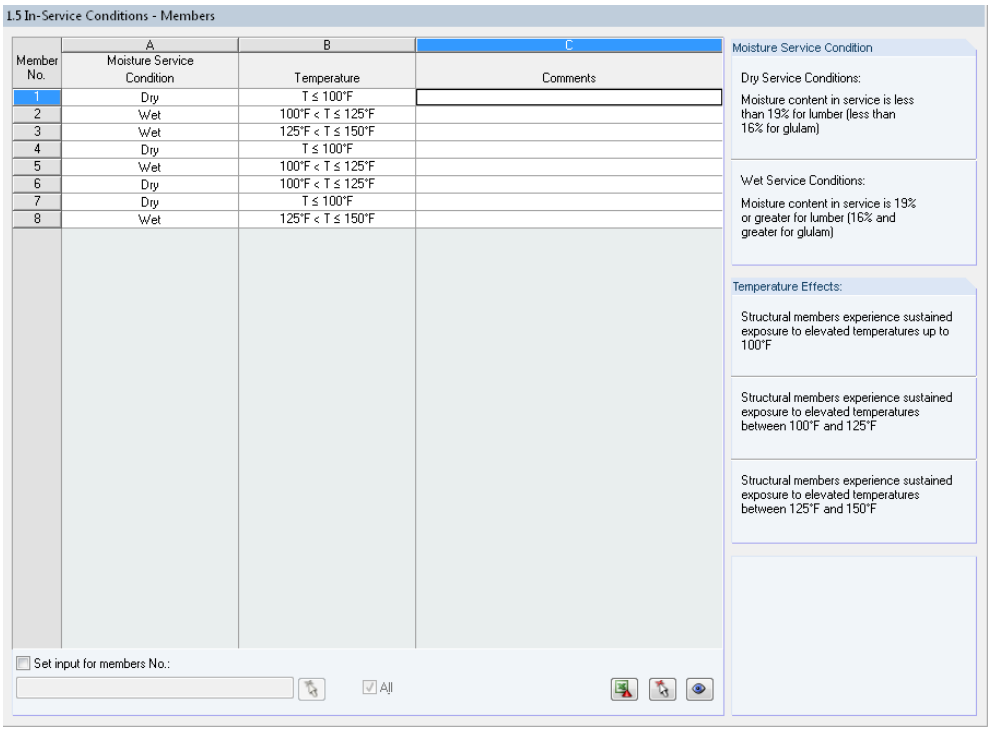
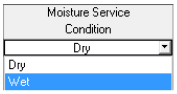
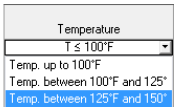


Figure 2.23: Window 1.5 *In-Service Conditions - Members*





By default, the program assigns dry service conditions and temperatures below 100 °F. If you want to allocate different moisture or temperature conditions to specific members, use the [▼] button to open the lists.

Below the *Settings* table, you find the *Set inputs for members No.* check box. If it is selected, the settings entered afterward will be applied to the selected or to *All* members. Members can be selected by entering their numbers or by selecting them graphically using the [↖] button. That option is useful when you want to assign identical conditions to several members. Please note that settings that have been already defined cannot be changed subsequently by this function.

The other buttons below the table have the following functions:

Button	Function
	Export of table to MS Excel or OpenOffice.org Calc
	Option to select member graphically in RFEM window and set its row in table
	View mode for switching to RFEM work window

Table 2.4: Buttons in Window 1.5 *In-Service Conditions - Members*

2.6 In-Service Conditions - Set of Members

This window is only available if one or more sets of members have been selected in Window 1.1 *General Data*.

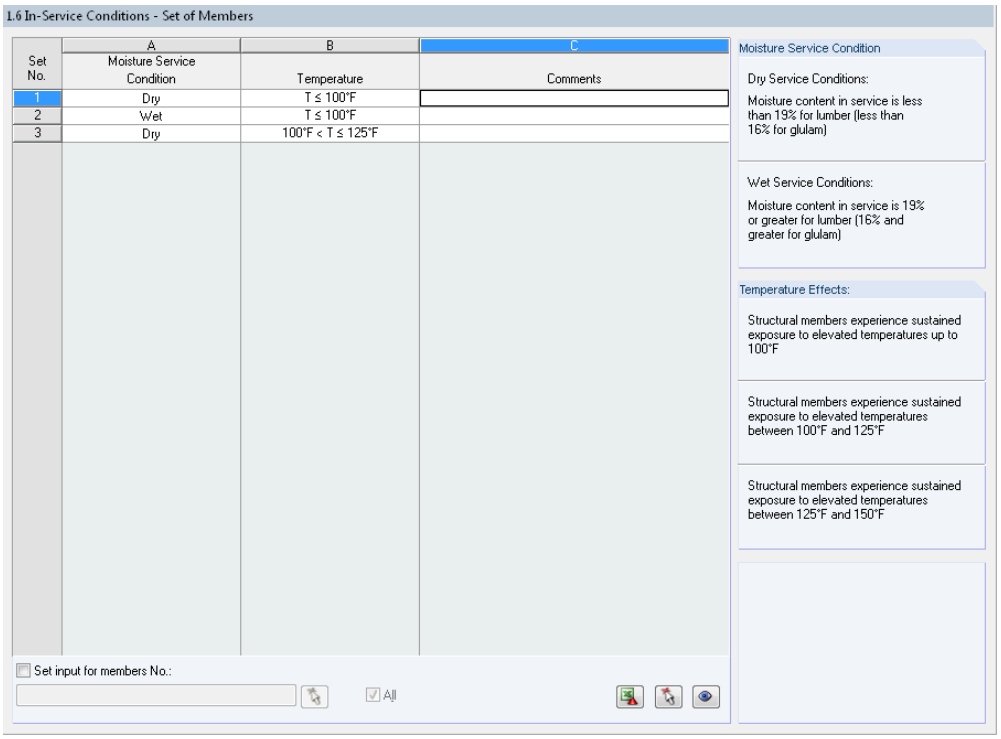


Figure 2.24: Window 1.6 *In-Service Conditions - Sets of Members*

The set-up of this window is similar to the one of the previous Window 1.5 *In-Service Conditions - Members*. Here you can assign temperature and moisture service conditions to each set of members.

2.7 Effective Lengths - Members

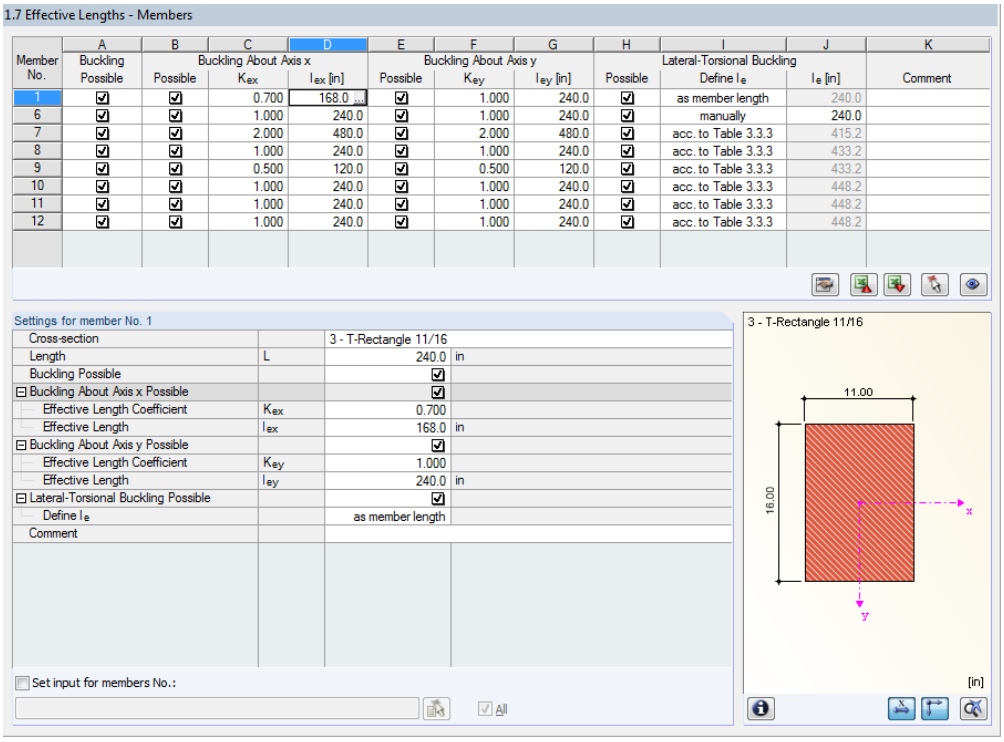
Details...

The appearance of the window depends on whether the stability analysis is carried out according to the equivalent member method or according to second-order analysis. You can specify that method in the *Stability* tab of the *Details* dialog box (see Figure 3.2, page 39). The following description refers to the equivalent member default method. For that, the parameters of buckling and lateral-torsional buckling must be defined.

If the stability analysis is deactivated in the *Stability* tab of the *Details* dialog box, Window 1.7 is not shown.

The window consists of two parts. The table in the upper part lists the factors for the lengths of buckling and lateral-torsional buckling as well as the equivalent member lengths of the members selected for design. The effective lengths defined in RFEM are preset. In the *Settings* section, you can see further information on the member whose row is selected in the upper table.

Click [↖] to select a member graphically and to show its row.



Member No.	A Buckling Possible	B Buckling About Axis x Possible	C K_{ex}	D l_{ex} [in]	E Buckling About Axis y Possible	F K_{ey}	G l_{ey} [in]	H Lateral-Torsional Buckling Possible	I Define l_e	J l_e [in]	K Comment
1	☑	☑	0.700	168.0	☑	1.000	240.0	☑	as member length	240.0	
6	☑	☑	1.000	240.0	☑	1.000	240.0	☑	manually	240.0	
7	☑	☑	2.000	480.0	☑	2.000	480.0	☑	acc. to Table 3.3.3	415.2	
8	☑	☑	1.000	240.0	☑	1.000	240.0	☑	acc. to Table 3.3.3	433.2	
9	☑	☑	0.500	120.0	☑	0.500	120.0	☑	acc. to Table 3.3.3	433.2	
10	☑	☑	1.000	240.0	☑	1.000	240.0	☑	acc. to Table 3.3.3	448.2	
11	☑	☑	1.000	240.0	☑	1.000	240.0	☑	acc. to Table 3.3.3	448.2	
12	☑	☑	1.000	240.0	☑	1.000	240.0	☑	acc. to Table 3.3.3	448.2	

Settings for member No. 1			
Cross-section		3 - T-Rectangle 11/16	
Length	L	240.0	in
Buckling Possible		☑	
⊟ Buckling About Axis x Possible		☑	
Effective Length Coefficient	K_{ex}	0.700	
Effective Length	l_{ex}	168.0	in
⊟ Buckling About Axis y Possible		☑	
Effective Length Coefficient	K_{ey}	1.000	
Effective Length	l_{ey}	240.0	in
⊟ Lateral-Torsional Buckling Possible		☑	
Define l_e		as member length	
Comment			

Figure 2.25: Window 1.7 *Effective Lengths - Members* for equivalent member method

The effective lengths can be entered manually in the table and in the *Settings* tree, or defined graphically in the work window after clicking [...]. This button is available as soon as you have clicked in the text box (see Figure above).

The *Settings* tree manages the following parameters:

- *Cross-Section*
- *Member Length*
- *Buckling Possible (corresponds to column A)*
- *Buckling About Axis x Possible (corresponds to columns B to D)*
- *Buckling About Axis y Possible (corresponds to columns E to G)*
- *Lateral-Torsional Buckling Possible (corresponds to columns H to J)*

In this table, you can specify for the currently selected member whether to carry out a buckling or a lateral-torsional buckling analysis. In addition to this, you can adjust the *Effective Length*

Coefficient for the respective directions. When a coefficient is modified, the equivalent member length is adjusted automatically, and vice versa.

You can also define the buckling length of a member in a dialog box. To open it, click the button shown on the left. It is located on the right below the upper table of the window.

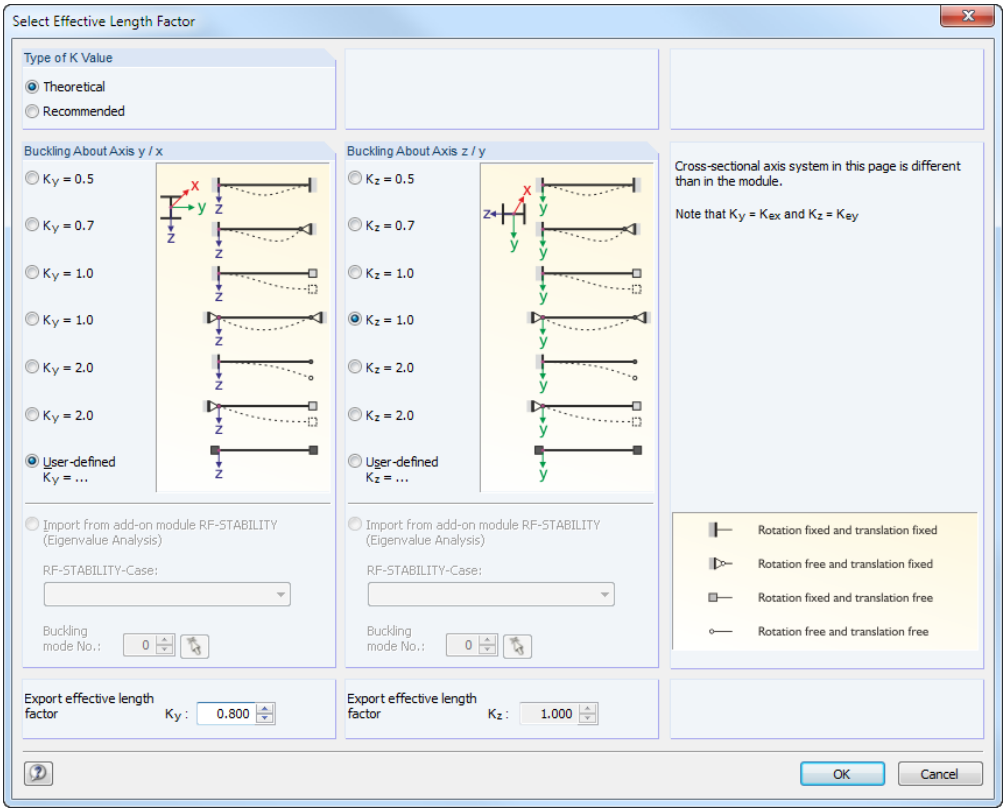


Figure 2.26: Dialog box *Select Effective Length Factor*

For each direction, you can select one of the buckling modes (theoretical and recommended values of buckling length factors according to [1] Table G1) or enter a *User-defined* effective length coefficient K_y.

If an eigenvalue analysis was carried out in the add-on module RF-STABILITY, you can also select a *Buckling Mode* to determine the factor.

Buckling Possible

The stability analysis for flexural buckling and lateral-torsional buckling requires the ability of members to resist compressive forces. Therefore, members for which such resistance is not possible because of the member type (for example tension members, elastic foundations, rigid couplings) are excluded from design in the first place. The corresponding rows appear dimmed and a note is displayed in the *Comment* column.

The *Buckling Possible* check boxes in table column A and in the *Settings* tree enable you to classify members as compression members or to exclude them from the stability analysis.

Buckling About Axis x / Buckling About Axis y

With the check boxes in the *Possible* table columns, you decide whether a member is susceptible to buckling about the x-axis and/or y-axis (see Chapter 2.3, page 19 for the axis systems). Those axes represent the local member axes, with the **x**-axis as the "major" and the **y**-axis the "minor" member axis. The buckling length coefficients $K_{e,x}$ and $K_{e,y}$ for buckling about the major or the minor axis can be selected freely.

You can check the position of the member axes in the cross-section graphic in Window 1.3 *Cross-Sections* (see Figure 2.16, page 18).

To access the RFEM work window, click the [View Mode] button. In the work window, you can display the local member axes by using the member's context menu or the *Display* navigator.

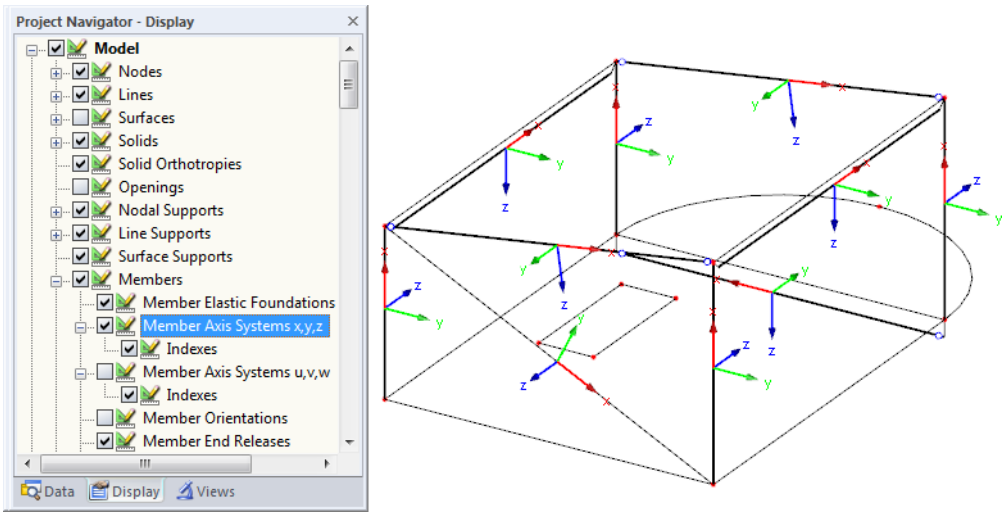


Figure 2.27: Selecting the member axis systems in the *Display* navigator of RFEM

If buckling is possible about one or even both member axes, you can enter the buckling length coefficients as well as the buckling lengths in the columns C and D respectively F and G. The same is possible in the *Settings* tree.

To specify the buckling lengths in the work window graphically, click [...]. This button becomes available when you click in a l_e text box (see Figure 2.25).

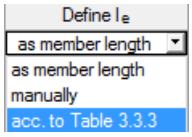
When you specify the buckling length coefficient K_e, the program determines the effective length l_e by multiplying the member length L by that buckling length coefficient. The text boxes for K_e and l_e are interactive.

Lateral-Torsional Buckling Possible

Table column H controls for which members a lateral-torsional buckling analysis is to be carried out.

Define l_e

The member lengths are preset in column I as equivalent member lengths relevant for lateral-torsional buckling. When you activate the check box in column I, you can specify the length for lateral-torsional buckling l_e in column J. You can also define it graphically after clicking […] as the distance of the lateral supports. Thus, you can adjust the boundary conditions of a structural component if it consists of several members between the supports.



When the option *acc. to Table 3.3.3* is selected, you can determine the lateral-torsional buckling length in accordance with [1] Table 3.3.3. A new dialog box is opened in which you can select the relevant loading conditions (see figure below).

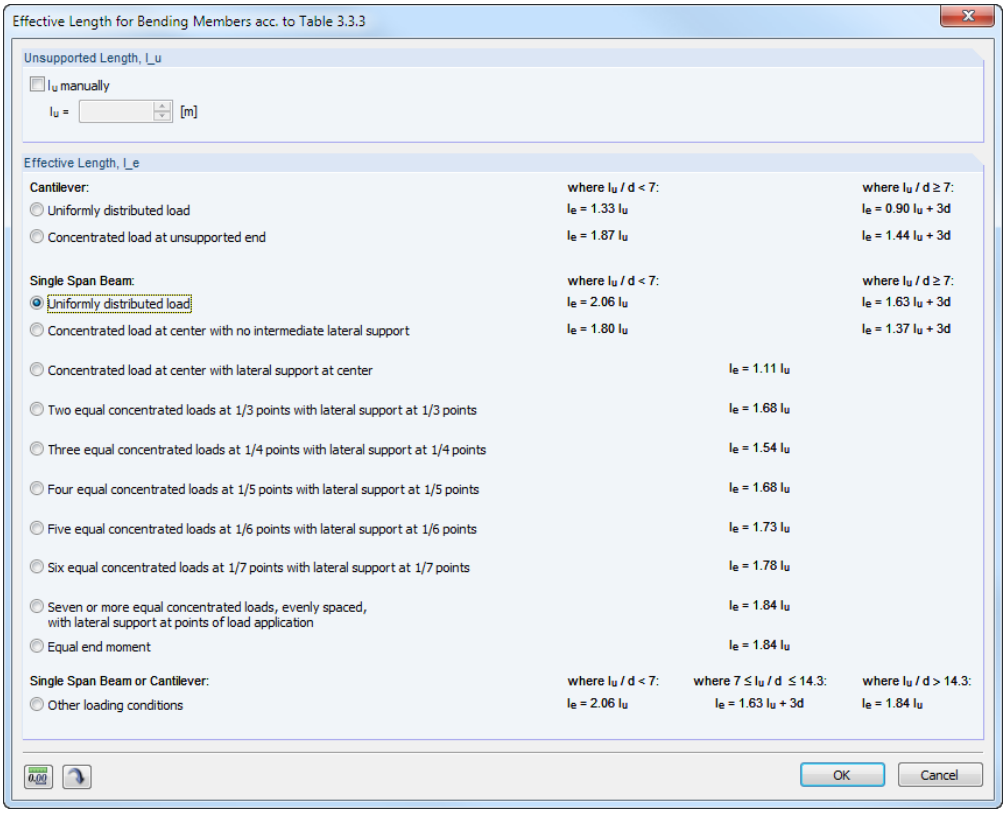


Figure 2.28: Dialog box *Effective Length for Bending Members acc. to Table 3.3.3*

Below the *Settings* table, you find the *Set inputs for members No.* check box. If it is selected, the settings entered afterward will be applied to the selected or to *All* members. Members can be selected by entering their numbers or by selecting them graphically using the [↖] button. That option is useful when you want to assign identical conditions to several members. Please note that settings that have been already defined cannot be changed subsequently by this function.

Comment

In the last table column, you can enter your own comments for each member to describe, for example, the defined equivalent member lengths.

Please note that curved members are excluded from the stability analysis. The Design Specification [1] provides no rules how to design members of that kind of geometry.

2.8 Effective Lengths - Sets of Members

This window is only available if one or more sets of members have been selected in Window 1.1 *General Data*. Additionally, the stability check must have been activated in the dialog box *Details*, tab *Stability* (see Figure 3.2, page 39).

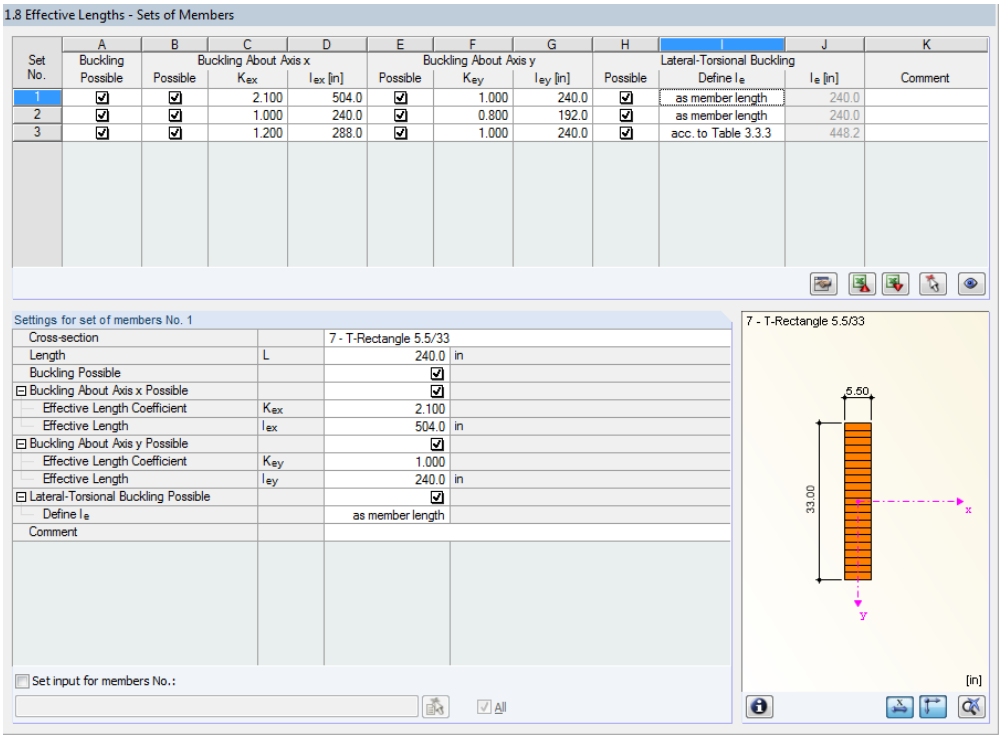


Figure 2.29: Window 1.8 *Effective Lengths - Sets of Members*

The set-up of this window is similar to the one of the previous Window 1.7 *Effective Lengths - Members*. Here you can enter the effective lengths for buckling as well as for lateral-torsional buckling about the two principal axes of the set of members as described in Chapter 2.7. They determine the boundary conditions of the entire set of members which is to be treated as an equivalent member.

Please note that curved sets of members are excluded from the stability analysis.

2.9 Additional Design Parameters

This window allows you to assign the adjustment factors which depend on the material of each member. The factors can be modified by clicking the [▼] button in column B.

1.9 Additional Design Parameters

Member No.	A Description	B Adjustment Factors Definition	C Symbol	D Value [-]	E acc. to	F Comment
1	Condition Treatment Factor	Air Dried	C_{ct}	1.000	6.3.5	
	Load Sharing Factor	Single Pile	C_{ls}	1.000, 1.000	6.3.11	
2	Incising Factor	Not Incised	C_i	-	4.3.8	
	Repetitive Factor	Not Repetitive	C_r	-	4.3.9	
3	Shear Reduction Factor	No Shear Reduction	C_{vr}	-	5.3.10	
	Shear Edge-Bonded Factor	Edge-Bonded	-	-	NDS Suppl.	
4	Shear Reduction Factor	Shear Reduction	C_{vr}	0.720	5.3.10	
	Shear Edge-Bonded Factor	Not Edge-Bonded (odd number of lams)	-	0.400	NDS Suppl.	
5	Shear Reduction Factor	No Shear Reduction	C_{vr}	-	5.3.10	
	Shear Edge-Bonded Factor	Not Edge-Bonded (even number of lams)	-	0.500	NDS Suppl.	
6	Shear Reduction Factor	No Shear Reduction	C_{vr}	-	5.3.10	
	Shear Edge-Bonded Factor	Edge-Bonded	-	-	NDS Suppl.	
7	Incising Factor	Not Incised	C_i	-	4.3.8	
	Repetitive Factor	Repetitive	C_r	1.150	4.3.9	
8	Incising Factor	Incised	C_i	0.950, 0.800, 1.000	4.3.8	
	Repetitive Factor	Not Repetitive	C_r	-	4.3.9	

Set input for members No.: All Material Category: All

Figure 2.30: Window 1.9 *Additional Design Parameters*

For sawn lumber members, you can determine whether the *Repetitive Factor* C_r and the *Incising Factor* C_i are to be applied in the calculation or not.

When a structural glued laminated timber member is used, you can specify the type of edge joint bonding and decide whether the *Shear Reduction Factor* C_{vr} is to be used.

For round timber poles and piles, it is necessary to specify the treatment condition (air-drying, kiln-drying, steam-conditioning, or boultonizing) and the load sharing condition (single pile or pile in group) so that the appropriate *Condition Treatment Factor* C_{ct} and *Load Sharing Factor* C_{ls} are applied.

The members can be filtered by *Material Category* via the list box below the table.

The other buttons have the following functions:

Button	Function
	Export of table to MS Excel or OpenOffice.org Calc
	Option to select member graphically in RFEM window and set its row in table
	View mode for switching to RFEM work window

Table 2.5: Buttons in Window 1.9 *Additional Design Parameters*

If the *Set inputs for members No.* check box has been activated, the settings entered afterward will be applied to the selected or to *All* members. Members can be selected by entering their numbers or by selecting them graphically using the [↖] button. That option is useful when you want to assign identical conditions to several members.

2.10 Curved Members

This window is available when you have selected at least one member with a curved shape in Window 1.1 *General Data* for the design. Curved members can be defined, for example, by using the line types "spline" or "arc".

The design of curved members is possible only for rectangular cross-sections and materials according to [2] Table 5A, Table 5B, Table 5C and Table 5D (i.e. structural glued laminated timber).

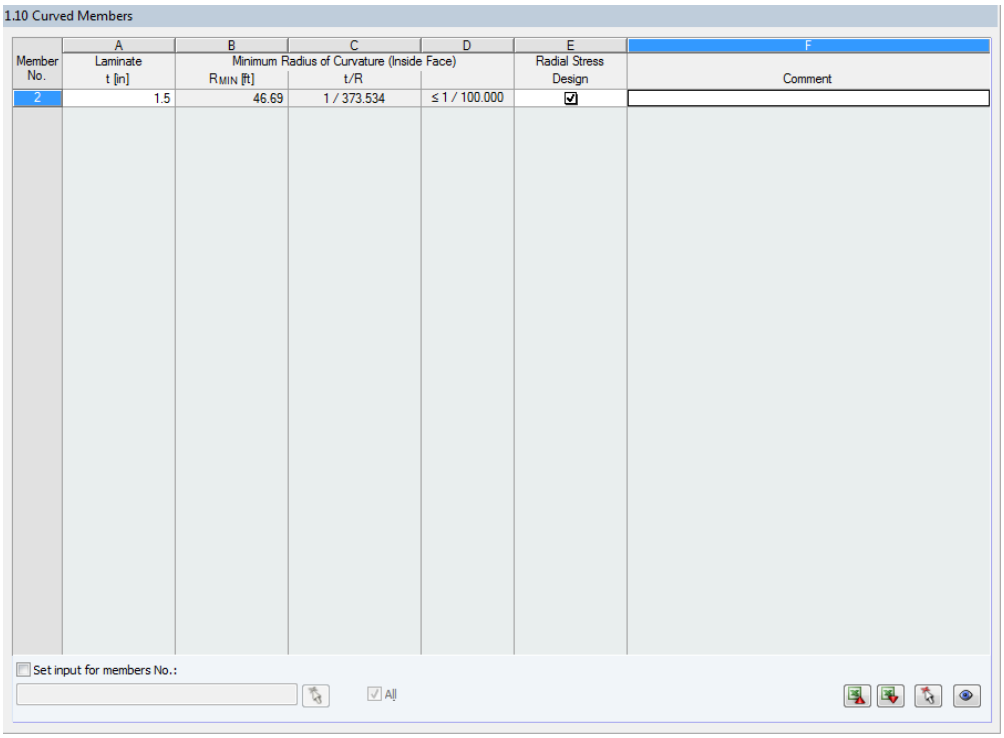


Figure 2.31: Window 1.10 *Curved Members*

Laminate

In this column, you have to specify the thickness *t* of the lamellas.

Minimum Radius of Curvature (Inside Face)

The program checks the ratio of the thicknesses of the lamellas and the minimal radius of curvature (inside face of member). According to [1] 5.3.8, the design is allowed only for ratios not exceeding 1/100 (hardwoods and Southern Pine) or 1/125 (other softwoods).

Radial Stress Design

Optionally RF-TIMBER AWC performs a check of the radial stresses. Where the bending moment is in the direction tending to increase the radius, the radial stress shall not exceed the adjusted radial tension design value, unless mechanical reinforcing sufficient to resist all radial stress is used. Where the bending moment is in the direction tending to decrease the radius, the radial stress shall not exceed the adjusted radial compression design value.

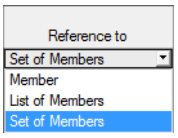
2.11 Serviceability Data

This input window controls several settings for the serviceability limit state design. It is only available if you have set the relevant entries in the *Serviceability Limit State* tab of Window 1.1 *General Data* (see Chapter 2.1.2, page 11).

1.11 Serviceability Data

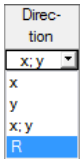
No.	A Reference to	B Member No.	C Reference Length Manually	D Reference Length L [ft]	E Direction	F Precamber $w_{c,x}$ [in]	G Precamber $w_{c,y}$ [in]	H Beam Type	I Comment
1	Member	1	☐	5.50	x; y	0.0	0.0	Cantilever End Free	
2	Member	2	☐	14.00	y		0.0	Beam	
3	Member	3	☐	8.00	y		0.0	Beam	
4	Member	4	☐	8.00	y		0.0	Beam	
5	Member	5	☐	8.00	R	0.0	0.0	Cantilever End Free	
6	Member	6	☐	8.00	y		0.0	Beam	
7	Member	7	☐	5.00	y		1.0	Beam	
8	Member	8	☐	5.50	x; y	0.0	1.0	Beam	
9	Set of Members	1	☐	32.00	x	0.0		Beam	
10	Set of Members	2	☐	16.00	x	0.0		Beam	
11	Set of Members	3	☐	14.00	R	0.0	0.0	Beam	
12	List of Members	102,121	☑	32.00	y		0.0	Beam	
13	List of Members	2,85,8,26	☑	16.00	y		0.0	Beam	
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									
33									

Figure 2.32: Window 1.11 *Serviceability Data*



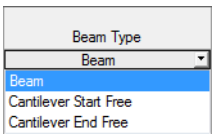
In column A, you decide whether you want to apply the deformation to single members, lists of members, or sets of members.

In table column B, you enter the numbers of the members or sets of members that you want to design. You can also click [...] to select them graphically in the RFEM work window. Then, the *Reference Length* appears in column D automatically. This column presets the lengths of the members, sets of members, or member lists. If required, you can adjust these values after selecting the *Manually* check box in column C.

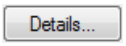


Column E controls the governing *Direction* for the deformation analysis. You can select the directions of the local member axes x and y (see Chapter 2.3, page 19 for the axis systems) and the resultant direction R.

In columns F and G, you can allow for some *Precamber* $w_{c,x}$ and $w_{c,y}$.



The *Beam Type* is important to correctly determine the limit deformations. Column H controls whether there is a beam or a cantilever and which end is not supported.



The settings in the *Serviceability* tab of the *Details* dialog box control whether the deformations are related to the undeformed initial model or to the shifted ends of members or sets of members (see Figure 3.3, page 40).

2.12 Fire Resistance - Members

This window manages the different fire resistance parameters. It is only available if you have set relevant entries in the *Fire Resistance* tab of Window 1.1 *General Data* (see Chapter 2.1.3, page 12).

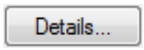
1.12 Fire Resistance - Members

No.	A Members No.	B Exp. to Fire Four Sides	C Exp. to Fire Top	D Exp. to Fire Bottom	E Exp. to Fire Left	F Exp. to Fire Right	G Comment
1	3-6	☐	☐	☑	☑	☑	
2	2,7,8	☐	☑	☑	☐	☐	
3	1	☑	☑	☑	☑	☑	
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							
31							
32							
33							

Figure 2.33: Window 1.12 *Fire Resistance - Members*

Table column A contains the members that are to be taken into account for the fire resistance design. Click [...] to graphically select the members in the RFEM work window.

In column B you specify if there is an *Exposure to Fire on Four Sides*. If the cross-section is not exposed to fire on all sides, clear the selection of the check box. Thus, the following columns become available in which you can specify the sides that are exposed to fire. The ideal remaining cross-section is then computed with those assumptions.



The general parameters of the fire resistance analysis are managed in the *Details* dialog box, tab *Fire Resistance Design* (see Figure 3.4, page 41).

2.13 Fire Resistance - Sets of Members

This window manages the fire resistance parameters of sets of members. It is displayed when you have selected one or more sets of members in Window 1.1 *General Data* and have allocated specific load cases or combinations in the *Fire Resistance* tab of that window.

1.13 Fire Resistance - Sets of Members

No.	A Sets of Members No.	B Exp. to Fire Four Sides	C Exp. to Fire Top	D Exp. to Fire Bottom	E Exp. to Fire Left	F Exp. to Fire Right	G Comment
1	1	☐	☐	☑	☑	☑	
2	2	☐	☑	☑	☐	☐	
3	3	☑	☑	☑	☑	☑	
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							
31							
32							
33							

Figure 2.34: Window 1.13 *Fire Resistance - Sets of Members*

The set-up of this window is similar to the one of the previous Window 1.12 *Fire Resistance - Members*. Here you can define the sides of the cross-section that are exposed to fire for the relevant set of members (see Chapter 2.12).

2.14 Tapered Members

This window is only available when you have selected at least one member with different cross-sections on both member ends for the design in Window 1.1 *General Data*. This window manages criteria such as the angle of taper of variable cross-sections, for example.

The design of curved members with variable cross-sections is possible only for rectangular sections and materials according to [2] Table 5A, Table 5B, Table 5C and Table 5D.

1.14 Tapered Members

	A	B	C	D	E	F
Member No.	Cross-Section Member Start	Member End	Length L [ft]	Angle of Taper θ [°]	Grain Parallel to Edge	Comment
9	T-Rectangle 7/40	T-Rectangle 7/20	15.00	6.34	+z/+y - axis	
10	T-Rectangle 7/20	T-Rectangle 7/40	15.00	6.34	+z/+y - axis	

Set input for members No.:

All

Figure 2.35: Window 1.14 *Tapered Members*

Cross-Section

The first two columns list the sections that are defined at the *Member Start* and *Member End*.

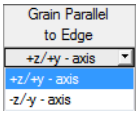
Length L

In this column, you can check the length of each tapered member.

Angle of Taper θ

RF-TIMBER AWC determines the inclination of the taper on the basis of geometric conditions. This angle is displayed for your information.

Grain Parallel to Edge



In column E, you specify the side of the member to which the direction of the grain is parallel. The "top" and "bottom" edges are clearly determined by the orientation of the local member axes z and y (see Figure 2.27, page 28).

In most cases, the grain runs parallel to the edge that is located in the direction of the positive axis +z/+y ("bottom"). This means that the beam is cut at its top side (see figure below).

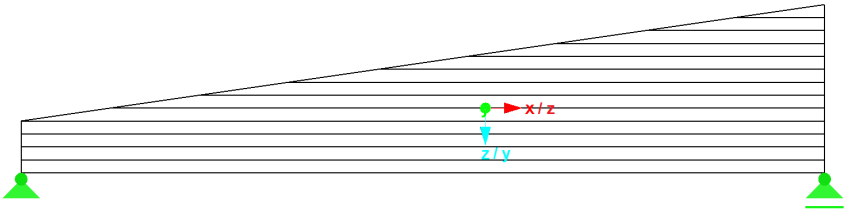


Figure 2.36: Grain parallel to edge in direction +z/+y

If the grain is parallel to the negative axis -z/-y ("top"), then the tapered member is cut at the bottom side. This case is an exception because taper cuts on the tension face of beams are not recommended according to [1] Chapter 5.3.9.

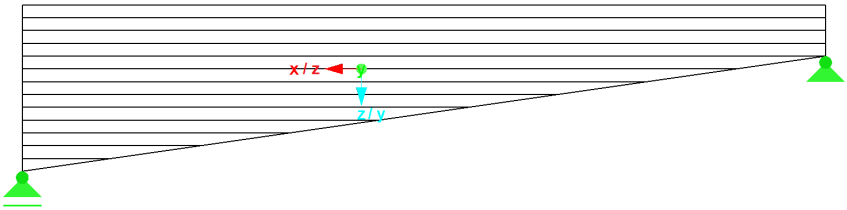


Figure 2.37: Grain parallel to edge in direction -z/-y

3. Calculation

3.1 Detail Settings

Before you start the calculation, you should check the design details. You can open the corresponding dialog box in all windows of the add-on module by clicking [Details].

The *Details* dialog box contains the following tabs:

- *Resistance*
- *Stability*
- *Serviceability*
- *Fire Resistance (ASD only)*
- *Other*

3.1.1 Resistance

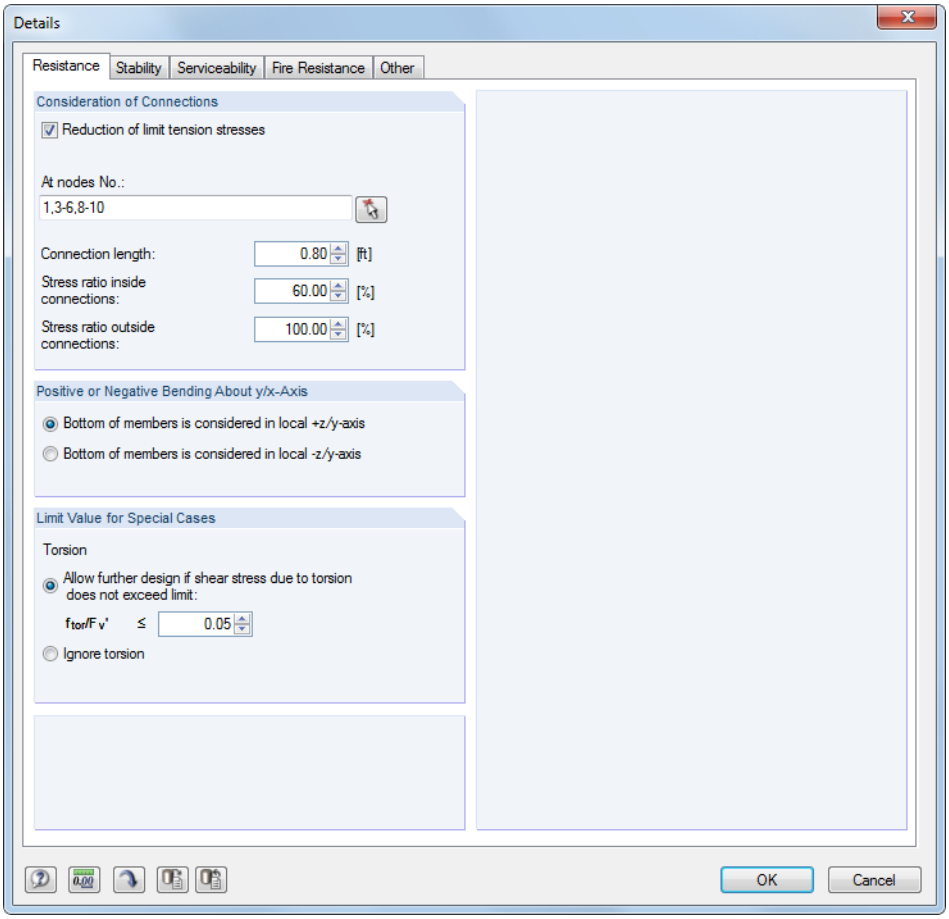


Figure 3.1: Dialog box *Details*, tab *Resistance*

Consideration of Connections

Often zones near member connections imply some weakening of the cross-section. It is possible to take into account this effect by a *Reduction of limit tension stresses*.

The numbers of the relevant *nodes* can be entered manually or selected graphically by clicking the [↖] button.

The *Connection length* defines the zone on the member where reduced stresses are considered. In the text box below, enter the allowable stress ratio for *Inside connections* in percent. If necessary, you can define the maximum design ratio for *Outside connections* of the connection zone.

Positive or Negative Bending About y/x-Axis

Structural glued laminated timber members stressed in bending about the y/x-axis have different reference bending design values for positive bending (bottom of beam stressed in tension) and negative bending (top of beam stressed in tension), see [2] Table 5A and Table 5C.

For RF-TIMBER AWC to apply the correct bending design value, you have to specify where the bottom side of members is located in the positive direction of the local z/y-axis or opposite.

Limit Value for Special Cases

Torsion design is not specified in ANSI/AWC NDS-2012. It is possible to ignore shear stresses due to torsion if a user-defined ratio of the torsional shear resistance is not exceeded (default: 5 %). If the limit is exceeded, a note appears in the result window. This limit setting is not part of the Design Specification [1]. Changing the limit is the responsibility of the user.

It is also possible to completely *Ignore torsion*.

3.1.2 Stability

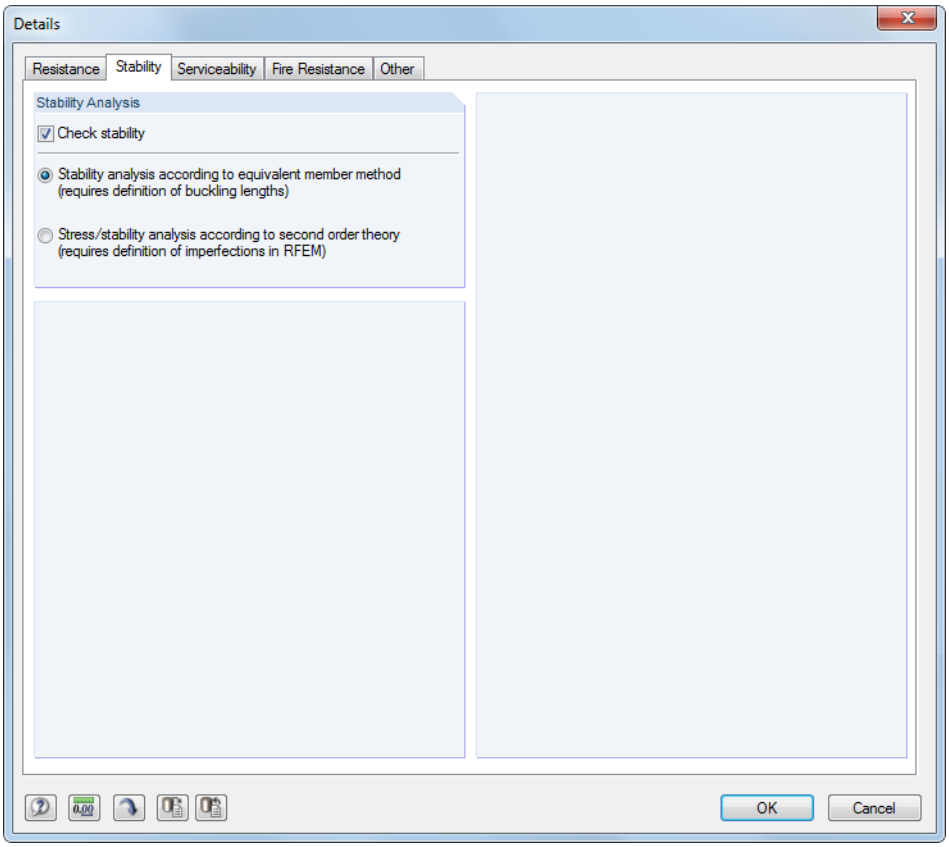
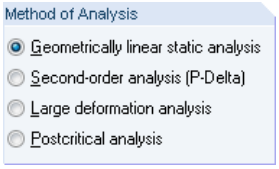


Figure 3.2: Dialog box *Details*, tab *Stability*

Stability Analysis

The *Check Stability* check box controls whether to run, in addition the cross-section design, a stability analysis. If you clear the check box, the input windows 1.7 and 1.8 will not be shown.



Equivalent member method: Setting method of analysis in RFEM

The *equivalent member method* uses the internal forces determined in RFEM. In this method, make sure that the **Geometrically linear static analysis** has been set (the default setting for load combinations is the 2nd order analysis). When you perform the stability analysis according to the equivalent member method, the effective lengths of the members and sets of members subject to compression or compression and bending must be specified in windows 1.7 and 1.8.

If the bearing capacity of the model is significantly affected by its deformations, we recommend selecting a calculation according to the *second order theory*. This approach additionally requires the definition of imperfections in RFEM and their consideration for the load combinations. The flexural buckling analysis is carried out during the calculation of the load combinations in RFEM.

The lateral-torsional buckling design must also be carried out for second order calculations. Thus, the lateral-torsional buckling lengths of members or sets of members must be specified in windows 1.7 and 1.8 *Effective Lengths* manually. This provision ensures that the lateral-torsional buckling analysis is performed with the appropriate factors (for example 1.0).

3.1.3 Serviceability

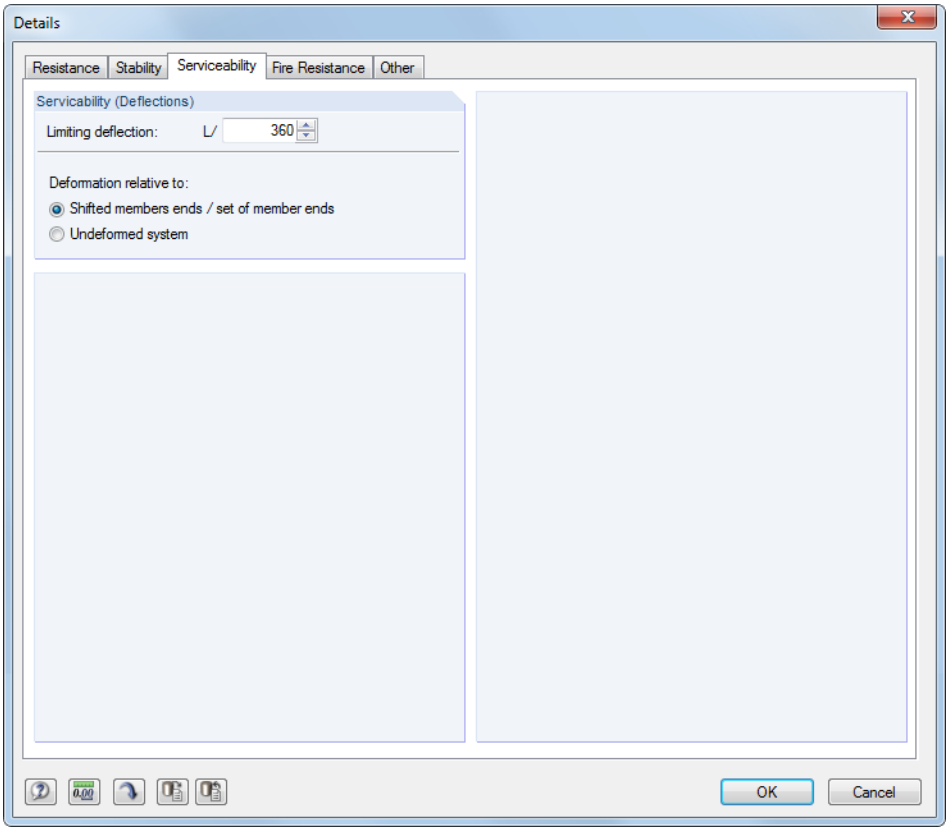


Figure 3.3: Dialog box *Details*, tab *Serviceability*

In this tab, it is possible to change the allowable deflection for the serviceability limit state design if the default value *L/360* is not appropriate.

With the options, you can decide whether the deformations is to be related to the *Shifted ends* of members or sets of members (i.e. connection line between start and end nodes of the deformed system) or to the initial *Undeformed system*. As a rule, the deformations have to be checked relative to the displacements in the entire structural system.

3.1.4 Fire Resistance

This tab manages the detailed settings for the fire resistance design (ASD only).

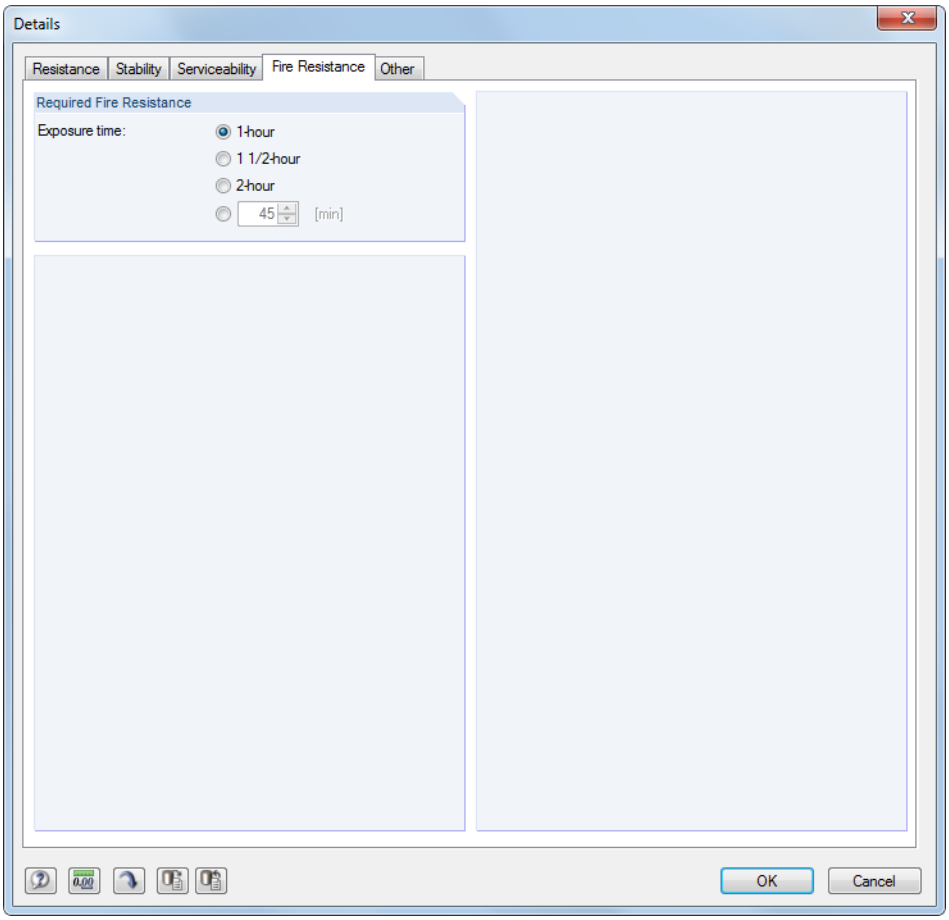


Figure 3.4: Dialog box *Details*, tab *Fire Resistance*

The *Exposure time* can be selected directly or defined individually by specifying the duration of the fire.

Additionally, some standard-specific parameters significant for the fire resistance design can be set in the *Standard* dialog box (see Figure 2.9, page 13).

3.1.5 Other

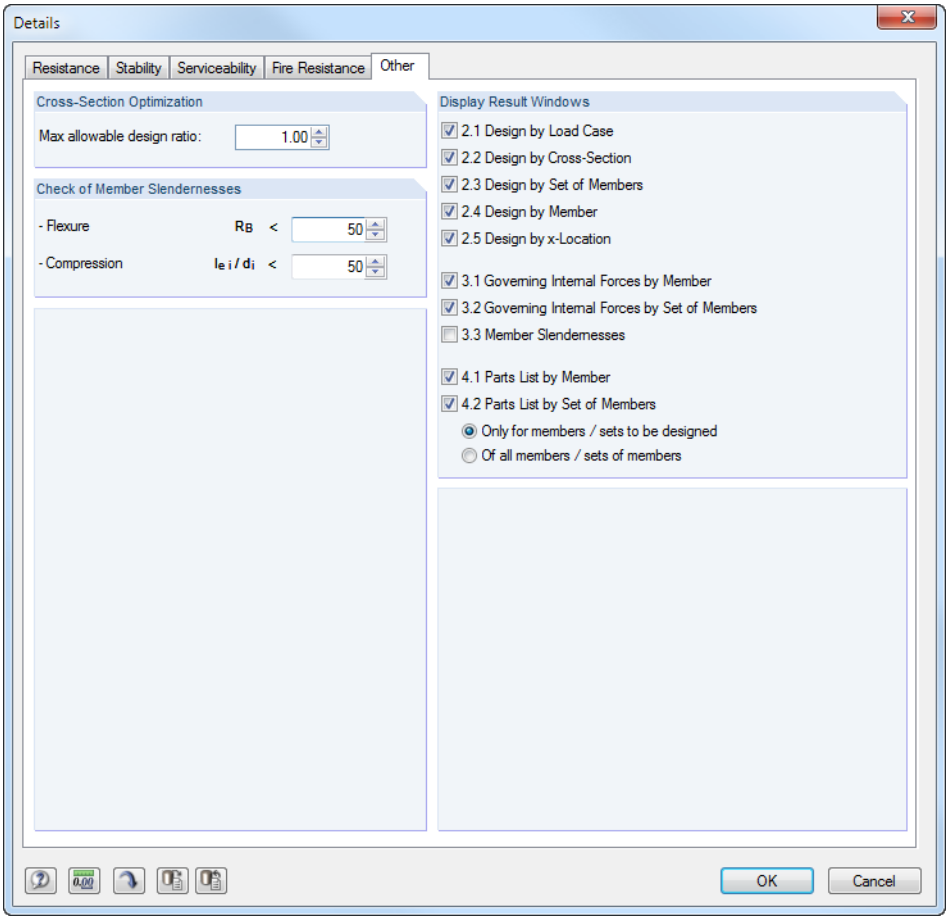


Figure 3.5: Dialog box *Details*, tab *Other*

Cross-Section Optimization

The optimization is targeted at the maximum design ratio of 1.00. If necessary, you can specify a different limit value in this text box.

Check of Member Slendernesses

In the two text boxes, you can specify the limit values of the member slenderness. You can define the rations separately for members with bending, R_B, and for members with compression, l_{ei}/d_i.

The limit values are compared to the real member slendernesses in Window 3.3. This window is available after the calculation (see Chapter 4.8, page 51) when the corresponding check box is selected in the *Display Result Windows* section of this dialog box.

Display Result Windows

In this dialog section, you can select the results windows including parts lists that you want to display. The windows are described in Chapter 4 *Results*.

The 3.3 *Member Slendernesses* window is deactivated by default.

3.2 Start Calculation

To start the calculation, click the [Calculation] button which is available in all input windows of the RF-TIMBER AWC add-on module.

RF-TIMBER AWC searches for the results of the load cases, load combinations, and result combinations to be designed. If these cannot be found, the program starts the RFEM calculation to determine the design relevant internal forces.

You can also start the calculation in the user interface of RFEM: In the dialog box *To Calculate* (menu *Calculate* → *To Calculate*), design cases of the add-on modules are listed like load cases and load combinations.

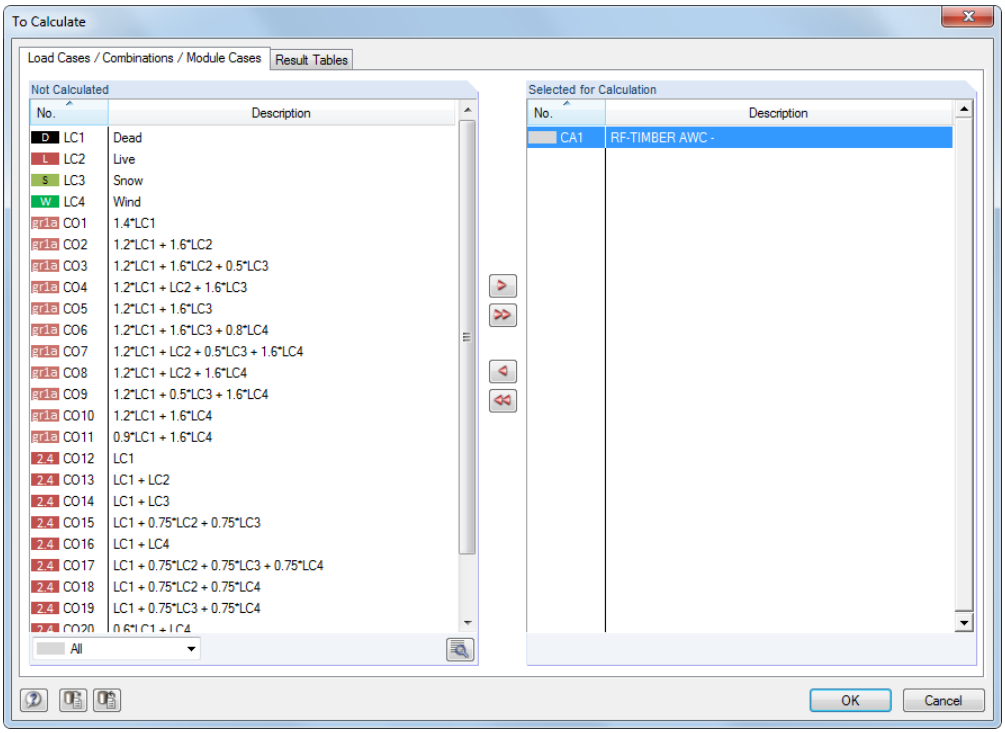
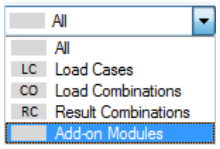


Figure 3.6: Dialog box *To Calculate*



If the RF-TIMBER AWC cases are missing in the *Not Calculated* section, select *All* or *Add-on Modules* in the drop-down list below the section.

To transfer the selected RF-TIMBER AWC cases to the list on the right, use the [▶] button. Click [OK] to start the calculation.

To calculate a design case directly, use the list in the toolbar. Select the RF-TIMBER AWC case in the toolbar list, and then click [Show Results].

Figure 3.7: Direct calculation of a RF-TIMBER AWC design case in RFEM

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

4. Results

The 2.1 *Design by Load Case* window is displayed immediately after the calculation.

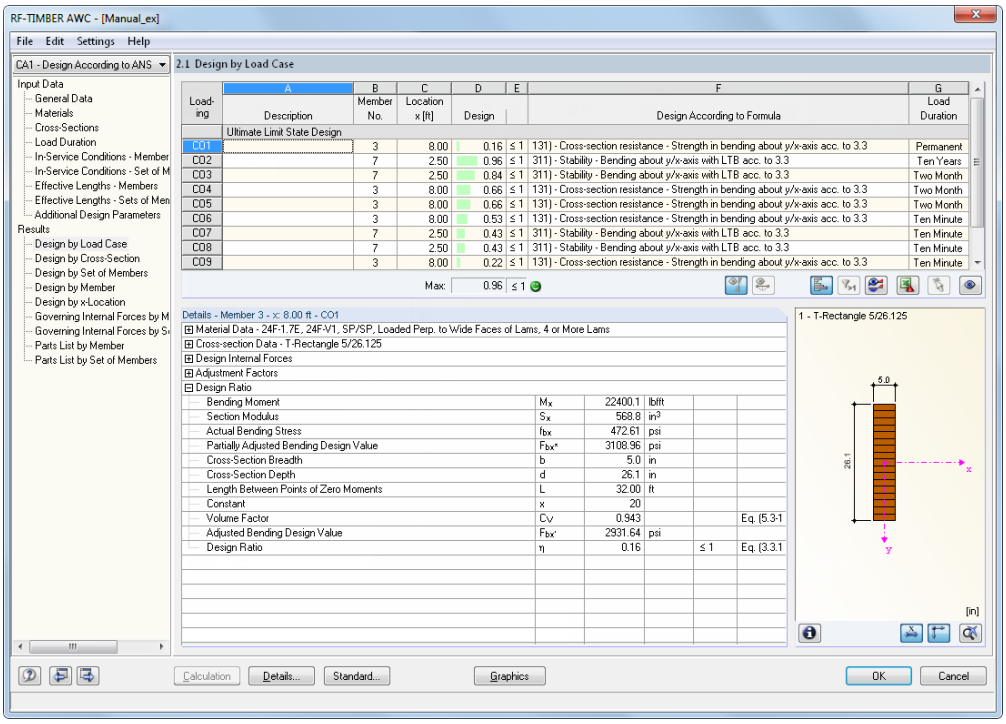
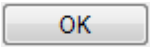


Figure 4.1: Results window with designs and intermediate values

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

Windows 3.1 and 3.2 list the governing internal forces. Window 3.3 informs you about the member slendernesses. The last two results windows 4.1 and 4.2 show the parts lists sorted by member and set of members.

Every window can be selected by clicking the corresponding entry in the navigator. To set the previous or next input window, use the buttons shown on the left. You can also use the function keys to select the next [F2] or previous [F3] window.



To save the results, click [OK]. You exit RF-TIMBER AWC and return to the main program.

Chapter 4 *Results* describes the different results windows one by one. Evaluating and checking results is described in Chapter 5 *Evaluation of Results* starting on page 54.

As there are different axis systems in RFEM and RF-TIMBER AWC (see Chapter 2.3, page 18), there are also different names of the internal forces, deformations and cross-section values.

INTERNAL FORCES	
RFEM	RF-TIMBER AWC
N	P (compression); T (tension)
V_y	V_y
V_z	V_x
M_T	M_{tor}
M_y	M_x
M_z	M_y

DEFORMATIONS	
RFEM	RF-TIMBER AWC
u_x	u_z
u_y	u_x
u_z	u_y
fi_x	fi_z
fi_y	fi_y
fi_z	fi_x

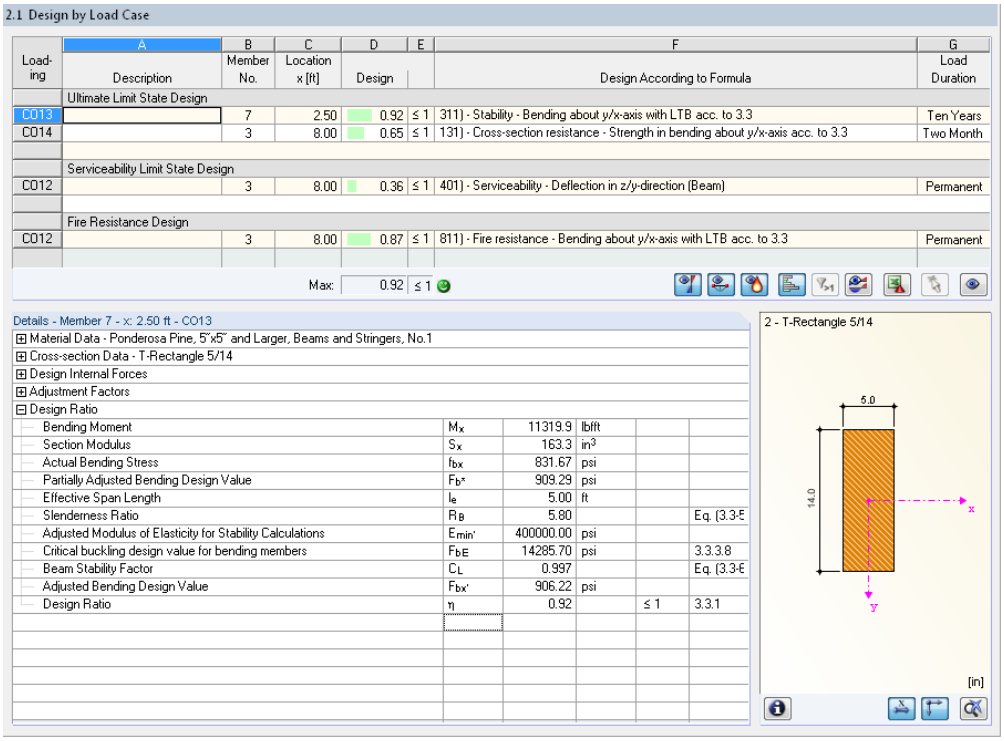
cross section characteristic value		
	RFEM	AWC
Moment of inertia	I_y	I_x
Moment of inertia	I_z	I_y
Elastic section modulus	S_y	S_x
Elastic section modulus	S_z	S_y
Statical moment of area	Q_y	Q_x
Statical moment of area	Q_z	Q_y
Section modulus for torsion	S_t	S_{tor}

Figure 4.2: Comparison between RFEM and RF-TIMBER AWC internal forces, deformations and cross-section values

4.1 Design by Load Case

The upper part of the window provides a summary, sorted by load cases, load combinations, and result combinations of the governing designs. Furthermore, the list is divided in *Ultimate Limit State Design*, *Serviceability Limit State Design* and *Fire Resistance Design* results.

The lower part gives detailed information on the cross-section properties, analyzed internal forces, and design parameters for the load case selected above.



2.1 Design by Load Case

Loading	A Description	B Member No.	C Location x [ft]	D Design	E	F Design According to Formula	G Load Duration
	Ultimate Limit State Design						
CO13		7	2.50	0.92	≤ 1	311) - Stability - Bending about y/x-axis with LTB acc. to 3.3	Ten Years
CO14		3	8.00	0.65	≤ 1	131) - Cross-section resistance - Strength in bending about y/x-axis acc. to 3.3	Two Month
	Serviceability Limit State Design						
CO12		3	8.00	0.36	≤ 1	401) - Serviceability - Deflection in z/y-direction (Beam)	Permanent
	Fire Resistance Design						
CO12		3	8.00	0.87	≤ 1	811) - Fire resistance - Bending about y/x-axis with LTB acc. to 3.3	Permanent
			Max:	0.92	≤ 1		

Details - Member 7 - x: 2.50 ft - CO13

⊞ Material Data - Ponderosa Pine, 5"x5" and Larger, Beams and Stringers, No.1					
⊞ Cross-section Data - T-Rectangle 5/14					
⊞ Design Internal Forces					
⊞ Adjustment Factors					
⊟ Design Ratio					
Bending Moment	M_x	11319.9	lbfft		
Section Modulus	S_x	163.3	in³		
Actual Bending Stress	f_{bx}	831.67	psi		
Partially Adjusted Bending Design Value	F_b^*	909.29	psi		
Effective Span Length	l_e	5.00	ft		
Slenderness Ratio	R_B	5.80			Eq. (3.3-E
Adjusted Modulus of Elasticity for Stability Calculations	E_{min}'	400000.00	psi		
Critical buckling design value for bending members	F_{bE}	14285.70	psi		
Beam Stability Factor	C_L	0.997			Eq. (3.3-E
Adjusted Bending Design Value	F_{bx}'	906.22	psi		
Design Ratio	η	0.92		≤ 1	3.3.1

Figure 4.3: Window 2.1 *Design by Load Case*

Description

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

Member No.

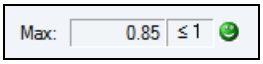
This column shows the number of the member that bears the maximum design ratio of every designed loading.

Location x

The column shows the x-location at which the maximum design ratio of each member occurs. For the table output, the program uses the following member x-locations:

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

Design



Columns D and E show the design conditions according to ANSI/AWC NDS-2012 [1].

The lengths of the colored scales represent the respective utilizations.

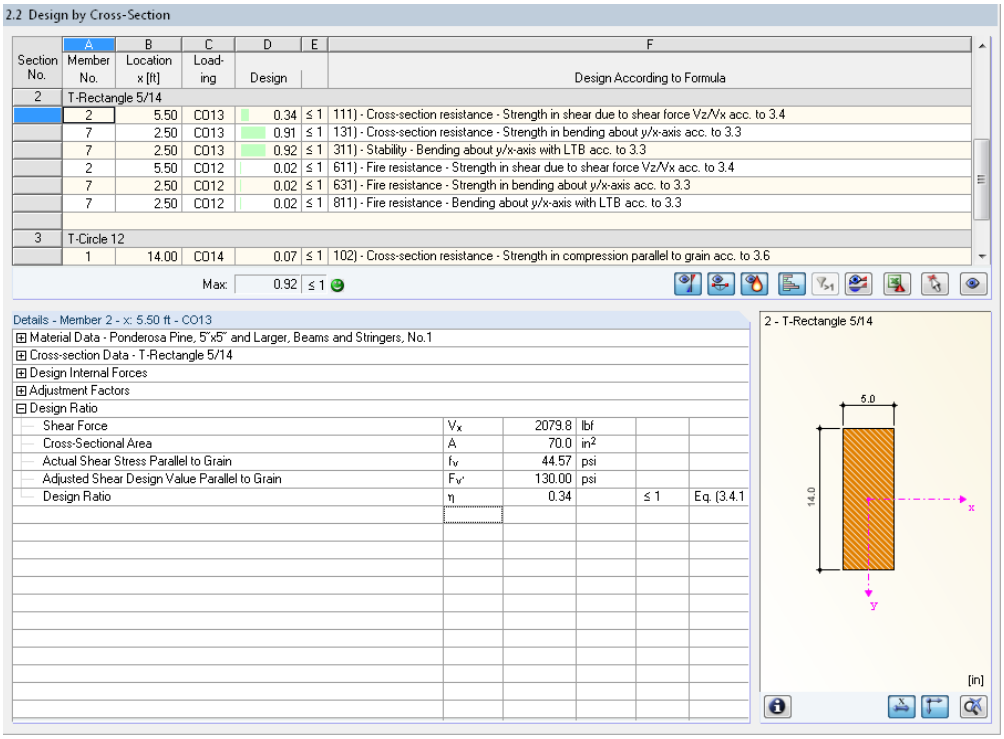
Design According to Formula

This column lists the equations of the Design Specification by which the designs have been performed.

Load Duration

In table column G, the load duration classes defined in Window 1.4 are listed (see Chapter 2.4, page 23).

4.2 Design by Cross-Section



2.2 Design by Cross-Section

Section No.	A Member No.	B Location x [ft]	C Load-ing	D Design	E	F Design According to Formula
2	T-Rectangle 5/14					
	2	5.50	CO13	0.34	≤ 1	111) - Cross-section resistance - Strength in shear due to shear force Vz/Vx acc. to 3.4
	7	2.50	CO13	0.91	≤ 1	131) - Cross-section resistance - Strength in bending about y/x-axis acc. to 3.3
	7	2.50	CO13	0.92	≤ 1	311) - Stability - Bending about y/x-axis with LTB acc. to 3.3
	2	5.50	CO12	0.02	≤ 1	611) - Fire resistance - Strength in shear due to shear force Vz/Vx acc. to 3.4
	7	2.50	CO12	0.02	≤ 1	631) - Fire resistance - Strength in bending about y/x-axis acc. to 3.3
	7	2.50	CO12	0.02	≤ 1	811) - Fire resistance - Bending about y/x-axis with LTB acc. to 3.3
3	T-Circle 12					
	1	14.00	CO14	0.07	≤ 1	102) - Cross-section resistance - Strength in compression parallel to grain acc. to 3.6
			Max:	0.92	≤ 1	

Details - Member 2 - x: 5.50 ft - CO13

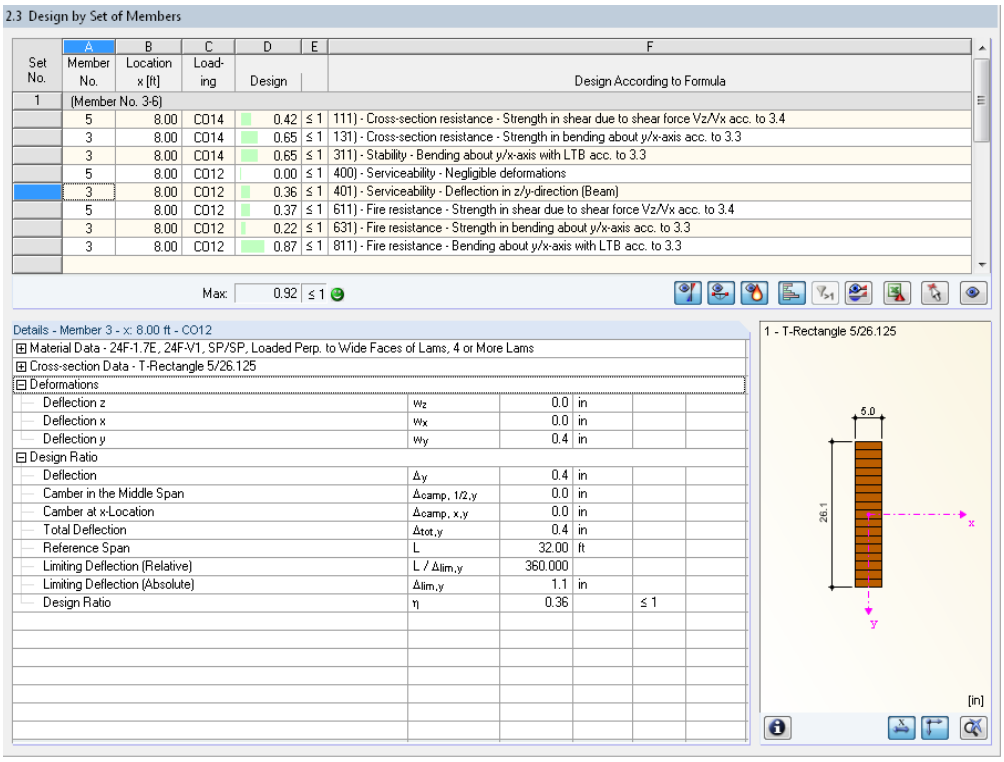
⊞ Material Data - Ponderosa Pine, 5"x5" and Larger, Beams and Stringers, No.1					
⊞ Cross-section Data - T-Rectangle 5/14					
⊞ Design Internal Forces					
⊞ Adjustment Factors					
⊟ Design Ratio					
Shear Force	V_x	2079.8	lbf		
Cross-Sectional Area	A	70.0	in²		
Actual Shear Stress Parallel to Grain	f_v	44.57	psi		
Adjusted Shear Design Value Parallel to Grain	$F_{v'}$	130.00	psi		
Design Ratio	η	0.34		≤ 1	Eq. (3.4.1

Figure 4.4: Window 2.2 *Design by Cross-Section*

This window lists the maximum ratios of all members and actions selected for design, sorted by cross-sections. The results are issued by cross-section design, stability analysis, serviceability limit state designs, and fire resistance design.

For tapered members, both cross-section descriptions are displayed in the table row next to the cross-section number.

4.3 Design by Set of Members



2.3 Design by Set of Members

Set No.	A Member No.	B Location x [ft]	C Load-ing	D Design	E	F Design According to Formula
1	(Member No. 3-6)					
	5	8.00	CO14	0.42	≤ 1	111) - Cross-section resistance - Strength in shear due to shear force Vz/Vx acc. to 3.4
	3	8.00	CO14	0.65	≤ 1	131) - Cross-section resistance - Strength in bending about y/x-axis acc. to 3.3
	3	8.00	CO14	0.65	≤ 1	311) - Stability - Bending about y/x-axis with LTB acc. to 3.3
	5	8.00	CO12	0.00	≤ 1	400) - Serviceability - Negligible deformations
	3	8.00	CO12	0.36	≤ 1	401) - Serviceability - Deflection in z/y-direction (Beam)
	5	8.00	CO12	0.37	≤ 1	611) - Fire resistance - Strength in shear due to shear force Vz/Vx acc. to 3.4
	3	8.00	CO12	0.22	≤ 1	631) - Fire resistance - Strength in bending about y/x-axis acc. to 3.3
	3	8.00	CO12	0.87	≤ 1	811) - Fire resistance - Bending about y/x-axis with LTB acc. to 3.3
	Max:			0.92	≤ 1	

Details - Member 3 - x: 8.00 ft - CO12

Material Data - 24F-1.7E, 24F-V1, SP/SP, Loaded Perp. to Wide Faces of Lams, 4 or More Lams				
Cross-section Data - T-Rectangle 5/26.125				
Deformations				
Deflection z	w_z	0.0	in	
Deflection x	w_x	0.0	in	
Deflection y	w_y	0.4	in	
Design Ratio				
Deflection	Δ_y	0.4	in	
Camber in the Middle Span	$\Delta_{camp,\ 1/2,y}$	0.0	in	
Camber at x-Location	$\Delta_{camp,\ x,y}$	0.0	in	
Total Deflection	$\Delta_{tot,y}$	0.4	in	
Reference Span	L	32.00	ft	
Limiting Deflection (Relative)	$L / \Delta_{lim,y}$	360.000		
Limiting Deflection (Absolute)	$\Delta_{lim,y}$	1.1	in	
Design Ratio	η	0.36		≤ 1

Figure 4.5: Window 2.3 *Design by Set of Members*

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

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

The output by sets of members clearly presents the design for an entire structural group (for example a chord).

4.4 Design by Member

2.4 Design by Member

Member No.	A Location x [ft]	B Load Case	C Design	D	E Design Acc. to Formula
1	Cross-section No. 3 - T-Circle 12				
	14.00	CO14	0.07	≤ 1	102) - Cross-section resistance - Strength in compression parallel to grain acc. to 3.6
	14.00	CO14	0.09	≤ 1	303) - Stability - Compression parallel to grain with buckling about both axes acc. to 3.6 and 3.7
	0.00	CO12	0.01	≤ 1	602) - Fire resistance - Strength in compression parallel to grain acc. to 3.6
	0.00	CO12	0.03	≤ 1	803) - Fire resistance - Compression parallel to grain with buckling about both axes acc. to 3.6 and 3.7
2	Cross-section No. 2 - T-Rectangle 5/14				
	5.50	CO13	0.34	≤ 1	111) - Cross-section resistance - Strength in shear due to shear force Vz/Vx acc. to 3.4
	0.00	CO13	0.91	≤ 1	131) - Cross-section resistance - Strength in bending about y/x-axis acc. to 3.3
	0.00	CO13	0.92	≤ 1	311) - Stability - Bending about y/x-axis with LTB acc. to 3.3
	Max:		0.92	≤ 1	

Details - Member 1 - x: 14.00 ft - CO14

⊞ Material Data - Pacific Coast Douglas Fir (Treated Round Timber Piles Graded per ASTM D25)				
⊞ Cross-section Data - T-Circle 12				
⊞ Design Internal Forces				
⊟ Adjustment Factors				
⊟ Compression Stress				
Reference Compression Design Value	F_c	1300.00	psi	Table 6A
Temperature Factor	C_t (F_c)	1.000		6.3.4
Condition Treatment Factor	C_{ct} (F_c)	1.000		6.3.5
Critical Section Factor	C_{cs} (F_c)	1.000		6.3.9
Load Sharing Factor	C_{ls} (F_c)	1.000		6.3.11
Load Duration Factor	C_D (F_c)	1.150		6.3.2
Adjusted Compression Design Value	F_c*	1495.00	psi	
⊟ Design Ratio				
Compressive Force	P	12580.0	lbf	
Cross-Sectional Area	A	113.1	in²	
Actual Compressive Stress Parallel to Grain	f_c	111.23	psi	
Partially Adjusted Compressive Design Value Parallel to Grain	F_c*	1495.00	psi	
Design Ratio	η	0.07		≤ 1 Eq. (3.6.3

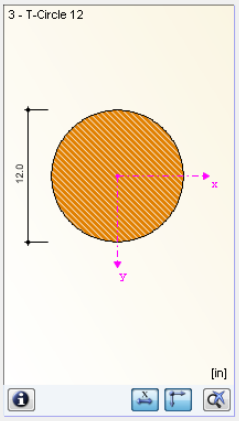


Figure 4.6: Window 2.4 *Design by Member*

This results window presents the maximum ratios for the individual designs sorted by member number. The columns are described in detail in Chapter 4.1 on page 45.

4.5 Design by x-Location

2.5 Design by x-Location

Member No.	A Location x [ft]	B Load Case	C Design	D	E Design Acc. to Formula
2	Cross-section No. 2 - T-Rectangle 5/14				
	0.00	CO12	0.00	≤ 1	111) - Cross-section resistance - Strength in shear due to shear force Vz/Vx acc. to 3.4
	0.00	CO12	0.03	≤ 1	131) - Cross-section resistance - Strength in bending about y/x-axis acc. to 3.3
	0.00	CO12	0.03	≤ 1	311) - Stability - Bending about y/x-axis with LTB acc. to 3.3
	0.00	CO12	0.00	≤ 1	111) - Cross-section resistance - Strength in shear due to shear force Vz/Vx acc. to 3.4
	0.00	CO12	0.03	≤ 1	131) - Cross-section resistance - Strength in bending about y/x-axis acc. to 3.3
	0.00	CO12	0.03	≤ 1	311) - Stability - Bending about y/x-axis with LTB acc. to 3.3
	1.38	CO12	0.01	≤ 1	111) - Cross-section resistance - Strength in shear due to shear force Vz/Vx acc. to 3.4
	1.38	CO12	0.02	≤ 1	131) - Cross-section resistance - Strength in bending about y/x-axis acc. to 3.3
	1.38	CO12	0.02	≤ 1	311) - Stability - Bending about y/x-axis with LTB acc. to 3.3
	Max:		0.83	≤ 1	

Details - Member 2 - x: 1.38 ft - CO12

⊞ Material Data - Ponderosa Pine, 5"x5" and Larger, Beams and Stringers, No.1				
⊞ Cross-section Data - T-Rectangle 5/14				
⊟ Design Internal Forces				
Normal Force	N_d	0.0	lbf	
Shear Force	$V_{x,d}$	-38.8	lbf	
Shear Force	$V_{y,d}$	0.0	lbf	
Torsional Moment	T_d	0.0	lbfft	
Bending Moment	$M_{x,d}$	244.9	lbfft	
Bending Moment	$M_{y,d}$	0.0	lbfft	
⊞ Adjustment Factors				
⊟ Design Ratio				
Bending Moment	M_x	244.9	lbfft	
Section Modulus	S_x	163.3	in³	
Actual Bending Stress	f_{bx}	17.99	psi	
Partially Adjusted Bending Design Value	F_b*	818.36	psi	
Adjusted Bending Design Value	F_{bx}'	818.36	psi	
Design Ratio	η	0.02		≤ 1 Eq. (3.3.1

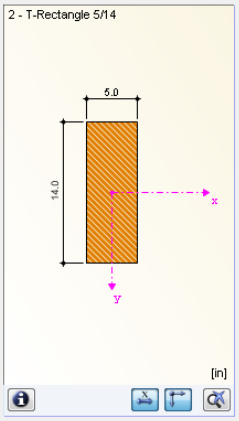


Figure 4.7: Window 2.5 *Design by x-Location*

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

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

4.6 Governing Internal Forces by Member

3.1 Governing Internal Forces by Member

Member No.	A Location x [ft]	B Load Case	C Forces [lbf] N	D V_y	E V_z	F Moments [lbfft] M_T	G M_y	H M_z	I Design According to Formula
1	Cross-section No. 3 - T-Circle 12								
	14.00	CO14	-12580.0	0.0	0.0	0.0	0.0	0.0	102) - Cross-section resistance - Strength in compression parallel to grain
	0.00	CO16	-2580.0	140.0	0.0	0.0	0.0	327.0	112) - Cross-section resistance - Strength in shear due to shear force Vy^
	14.00	CO16	-2580.0	-140.0	0.0	0.0	0.0	327.0	152) - Cross-section resistance - Strength in bending about z/y-axis and c
	14.00	CO14	-12580.0	0.0	0.0	0.0	0.0	0.0	303) - Stability - Compression parallel to grain with buckling about both ax
	14.00	CO16	-2580.0	-140.0	0.0	0.0	0.0	327.0	343) - Stability - Bending about z/y-axis without LTB and compression witl
2	Cross-section No. 2 - T-Rectangle 5/14								
	5.50	CO12	0.0	0.0	-80.0	0.0	0.0	0.0	111) - Cross-section resistance - Strength in shear due to shear force Vz^
	0.00	CO12	0.0	0.0	-25.0	0.0	288.7	0.0	131) - Cross-section resistance - Strength in bending about y/x-axis acc. t
	0.00	CO12	0.0	0.0	-25.0	0.0	288.7	0.0	311) - Stability - Bending about y/x-axis with LTB acc. to 3.3
3	Cross-section No. 1 - T-Rectangle 5/26.125								
	0.00	CO14	15.9	0.0	7500.0	0.0	60000.0	0.0	111) - Cross-section resistance - Strength in shear due to shear force Vz^
	8.00	CO14	-0.1	0.0	2500.0	0.0	80000.0	0.0	131) - Cross-section resistance - Strength in bending about y/x-axis acc. t
	8.00	CO14	-0.1	0.0	2500.0	0.0	80000.0	0.0	311) - Stability - Bending about y/x-axis with LTB acc. to 3.3
4	Cross-section No. 1 - T-Rectangle 5/26.125								
	0.00	CO14	0.1	0.0	2500.0	0.0	80000.0	0.0	111) - Cross-section resistance - Strength in shear due to shear force Vz^
	0.00	CO14	0.1	0.0	2500.0	0.0	80000.0	0.0	131) - Cross-section resistance - Strength in bending about y/x-axis acc. t
	0.00	CO14	0.1	0.0	2500.0	0.0	80000.0	0.0	311) - Stability - Bending about y/x-axis with LTB acc. to 3.3
5	Cross-section No. 1 - T-Rectangle 5/26.125								
	8.00	CO14	68.6	0.0	-12499.8	0.0	0.0	0.0	111) - Cross-section resistance - Strength in shear due to shear force Vz^
	0.00	CO14	48.1	0.0	-2499.8	0.0	60000.0	0.0	131) - Cross-section resistance - Strength in bending about y/x-axis acc. t
	0.00	CO14	48.1	0.0	-2499.8	0.0	60000.0	0.0	311) - Stability - Bending about y/x-axis with LTB acc. to 3.3
6	Cross-section No. 1 - T-Rectangle 5/26.125								
	0.00	CO14	68.2	0.0	12499.8	0.0	0.0	0.0	111) - Cross-section resistance - Strength in shear due to shear force Vz^
	8.00	CO14	47.7	0.0	7499.8	0.0	60000.0	0.0	131) - Cross-section resistance - Strength in bending about y/x-axis acc. t
	8.00	CO14	47.7	0.0	7499.8	0.0	60000.0	0.0	311) - Stability - Bending about y/x-axis with LTB acc. to 3.3
7	Cross-section No. 2 - T-Rectangle 5/14								
	0.00	CO12	0.0	0.0	25.0	0.0	288.7	0.0	111) - Cross-section resistance - Strength in shear due to shear force Vz^

Figure 4.8: Window 3.1 *Governing Internal Forces by Member*

For each member, this window displays the governing internal forces, that is, those internal forces that result in the maximum utilization in each design.

Location x

At this x-location of the member, the respective maximum design ratio occurs.

Load Case

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

Forces / Moments

For each member, this column displays the axial and shear forces as well as the torsional and bending moments producing maximum ratios in the respective cross-section designs, stability analyses, serviceability limit state designs, and fire resistance designs.

Design According to Formula

The final column provides information on the type of design and the equations by which the designs according to [1] have been performed.

4.7 Governing Internal Forces by Set of Members

3.2 Governing Internal Forces by Set of Members

Set No.	A Location x [ft]	B Load Case	C Forces [lbf] N	D Forces [lbf] V_y	E Forces [lbf] V_z	F Moments [lbfft] M_T	G Moments [lbfft] M_y	H Moments [lbfft] M_z	I Design According to Formula
1	(Member No. 3-6)								
	8.00	CO14	68.6	0.0	-12499.8	0.0	0.0	0.0	111) - Cross-section resistance - Strength in shear due to shear force Vz/Vx a
	8.00	CO14	-0.1	0.0	2500.0	0.0	80000.0	0.0	131) - Cross-section resistance - Strength in bending about y/x-axis acc. to 3.
	8.00	CO14	-0.1	0.0	2500.0	0.0	80000.0	0.0	311) - Stability - Bending about y/x-axis with LTB acc. to 3.3
2	(Member No. 2,7,8)								
	5.50	CO12	0.0	0.0	-80.0	0.0	0.0	0.0	111) - Cross-section resistance - Strength in shear due to shear force Vz/Vx a
	2.50	CO12	0.0	0.0	0.0	0.0	320.0	0.0	131) - Cross-section resistance - Strength in bending about y/x-axis acc. to 3.
	2.50	CO12	0.0	0.0	0.0	0.0	320.0	0.0	311) - Stability - Bending about y/x-axis with LTB acc. to 3.3
3	(Member No. 1)								
	14.00	CO14	-12580.0	0.0	0.0	0.0	0.0	0.0	102) - Cross-section resistance - Strength in compression parallel to grain acc
	0.00	CO16	-2580.0	140.0	0.0	0.0	0.0	327.0	112) - Cross-section resistance - Strength in shear due to shear force Vy/Vy a
	14.00	CO16	-2580.0	-140.0	0.0	0.0	0.0	327.0	152) - Cross-section resistance - Strength in bending about z/y-axis and comp
	14.00	CO14	-12580.0	0.0	0.0	0.0	0.0	0.0	303) - Stability - Compression parallel to grain with buckling about both axes a
	14.00	CO16	-2580.0	-140.0	0.0	0.0	0.0	327.0	343) - Stability - Bending about z/y-axis without LTB and compression with bu

Figure 4.9: Window 3.2 *Governing Internal Forces by Set of Members*

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

4.8 Member Slendernesses

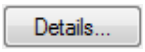
3.3 Member Slendernesses

Member No.	A Loss of Stability Under Stress	B Buckling About Axis x l_{ex} [ft]	C d [in]	D l_{ex} / d [-]	E Ratio	F Buckling About Axis y l_{ey} [ft]	G b [in]	H l_{ey} / b [-]	I Ratio	J Lateral Buckling l_e [ft]	K b [in]	L d [in]	M R_B [-]	N Ratio
1	Compression	14.00	14.3	11.748	0.23	14.00	7.0	24.000	0.48	-	-	-	-	-
2	Compression / Flexure	16.00	14.3	13.427	0.27	5.50	7.0	9.429	0.19	5.50	7.0	14.3	4.389	0.09
3	Compression / Flexure	32.00	26.0	14.769	0.30	8.00	5.0	19.200	0.38	8.00	5.0	26.0	9.992	0.20
4	Flexure	-	-	-	-	-	-	-	-	8.00	5.0	26.0	9.992	0.20
5	Compression / Flexure	32.00	26.0	14.769	0.30	8.00	5.0	19.200	0.38	8.00	5.0	26.0	9.992	0.20
6	Flexure	-	-	-	-	-	-	-	-	8.00	5.0	26.0	9.992	0.20
7	Compression / Flexure	16.00	14.3	13.427	0.27	5.00	7.0	8.571	0.17	5.00	7.0	14.3	4.185	0.08
8	Flexure	-	-	-	-	-	-	-	-	5.50	7.0	14.3	4.389	0.09

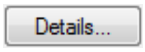
Compression Members:
Max l_{ex} / d : 14.769 ≤ 50
Max l_{ey} / b : 24.000 ≤ 50

Bending Members:
Max R_B : 9.992 ≤ 50

Figure 4.10: Window 3.3 *Member Slendernesses*



This results window is shown only when you have selected the respective check box in the *Other* tab of the *Details* dialog box (see Figure 3.5, page 42).



The table lists the effective slendernesses of the designed members which can lose their stability as compression members, bending members or combinations of both. They were determined depending on the type of load and occurrence of buckling or lateral-torsional buckling. At the end of the list, you find a comparison with the limit values that have been defined in the *Details* dialog box, tab *Other* (see Figure 3.5, page 42).

This window is displayed only for information. No design of the slendernesses is carried out.

4.9 Parts List by Member

Finally, RF-TIMBER AWC provides a summary of all cross-sections that are included in the design case.

4.1 Parts List by Member

Part No.	A Cross-Section Description	B Number of Members	C Length [ft]	D Total Length [ft]	E Surface Area [ft²]	F Volume [ft³]	G Unit Weight [lb/ft]	H Weight [lb]	I Total Weight [ton]
1	2 - T-Rectangle 7/14.3	1	14.00	14.00	49.70	9.73	20.25	283.43	0.127
2	2 - T-Rectangle 7/14.3	4	5.50	22.00	78.10	15.29	20.25	111.35	0.199
3	1 - T-Rectangle 5/26	8	8.00	64.00	330.67	57.78	32.67	261.33	0.933
4	2 - T-Rectangle 7/14.3	2	5.00	10.00	35.50	6.95	20.25	101.23	0.090
5	3 - T-Circle 2.4	2	14.00	28.00	17.59	0.88	1.05	14.75	0.013
6	6 - Beams and Stringers 6x10 | ANSI/AWC NDS-20	2	5.50	11.00	27.04	3.89	12.78	70.31	0.063
7	5 - Glulam (WS) 2.5x6 | ANSI/AWC NDS-2012	4	8.00	32.00	45.33	3.33	3.77	30.15	0.054
8	6 - Beams and Stringers 6x10 | ANSI/AWC NDS-20	1	5.00	5.00	12.29	1.77	12.78	63.92	0.029
Sum		24		186.00	596.23	99.62			1.507

Figure 4.11: Window 4.1 *Parts List by Member*

By default, the list contains only the designed members. If you need a parts list of all members of the model, select the corresponding option in the *Details* dialog box, tab *Other* (see Figure 3.5, page 42).

Part No.

The program automatically assigns item numbers to similar members.

Cross-Section Description

This column lists the cross-section numbers and descriptions.

Number of Members

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

Length

This column displays the respective length of an individual member.

Total Length

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

Surface Area

For each part, the program indicates the surface area relative to the total length. The surface area is determined from the *Surface Area* of the cross-sections that can be seen in Windows 1.3 and 2.1 to 2.5 (see Figure 2.20, page 21).

Volume

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

Unit Weight

The *Unit Weight* of the cross-section is relative to the length of one meter.

Weight

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

Total Weight

The final column indicates the total weight of each part.

Sum

At the bottom of the list, you find a sum of the values in the columns B, D, E, F, and I. The last cell of the column *Total Weight* gives information about the total amount of timber required.

4.10 Parts List by Set of Members

4.2 Parts List by Set of Members

Part No.	A Set of Members Description	B Number of Set	C Length [ft]	D Total Length [ft]	E Surface Area [ft²]	F Volume [ft³]	G Unit Weight [lb/ft]	H Weight [lb]	I Total Weight [ton]
1	Continuous beam 1.1	1	32.00	32.00	165.33	28.89	32.67	1045.32	0.467
2	Continuous beam 2.1	1	16.00	16.00	56.80	11.12	20.25	323.92	0.145
3	Column 1.1	1	14.00	14.00	49.70	9.73	20.25	283.43	0.127
4	Continuous beam 1.2	1	32.00	32.00	45.33	3.33	3.77	120.61	0.054
5	Continuous beam 2.2	1	16.00	16.00	39.33	5.65	12.78	204.54	0.091
6	Column 1.2	1	14.00	14.00	8.80	0.44	1.05	14.75	0.007
7	Continuous beam 1.3	1	32.00	32.00	165.33	28.89	32.67	1045.32	0.467
8	Continuous beam 2.3	1	16.00	16.00	56.80	11.12	20.25	323.92	0.145
9	Column 1.3	1	14.00	14.00	8.80	0.44	1.05	14.75	0.007
Sum		9		186.00	596.23	99.62			1.507

Figure 4.12: Window 4.2 *Parts List by Set of Members*

The last results window is displayed if you have selected at least one set of members for design. It summarizes an entire structural group (for example a chord) in a parts list.

Details on the various columns can be found in the previous chapter. If there are different cross-sections in the set of members, the program averages the surface area, the volume, and the cross-section weight.

5. Evaluation of Results

You can evaluate the design results in different ways. For this, the buttons located below the upper results tables are very useful.

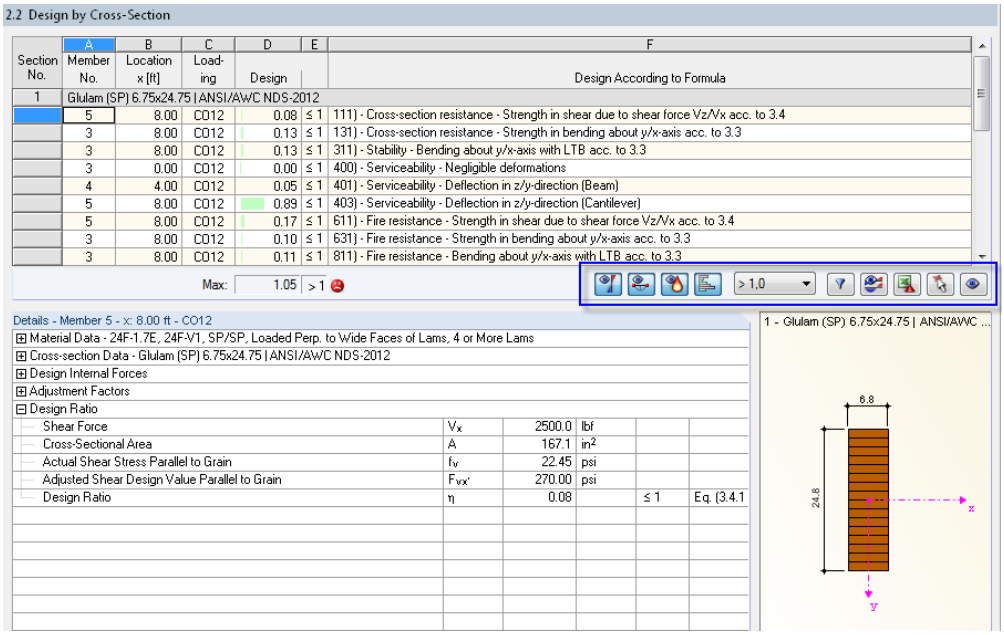


Figure 5.1: Buttons for evaluation of results

The buttons have the following functions:

Button	Description	Function
	ULS Design	Shows or hides the results of the ultimate limit state design
	SLS Design	Shows or hides the results of the serviceability limit state design
	Fire Resistance Design	Shows or hides the results of the fire resistance design
	Show Color Bars	Shows or hides the colored relation scales in the results windows
> 1,0	Filter Options	Displays only rows with ratios greater than the filter criterion set in list box: design ratios > 1, maximum, or user-defined limit
	Result Diagrams	Opens the window *Result Diagram on Member* → Chapter 5.2, page 57
	Excel Export	Exports the table to MS Excel / OpenOffice → Chapter 7.4.3, page 67
	Member Selection	Allows you to graphically select a member to display its results in the table
	View Mode	Jumps to the RFEM work window to change the view

Table 5.1: Buttons in results windows 2.1 through 2.5

5.1 Results in the RFEM Model

To evaluate the design results, you can also use the RFEM work window.

RFEM background graphic and view mode

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

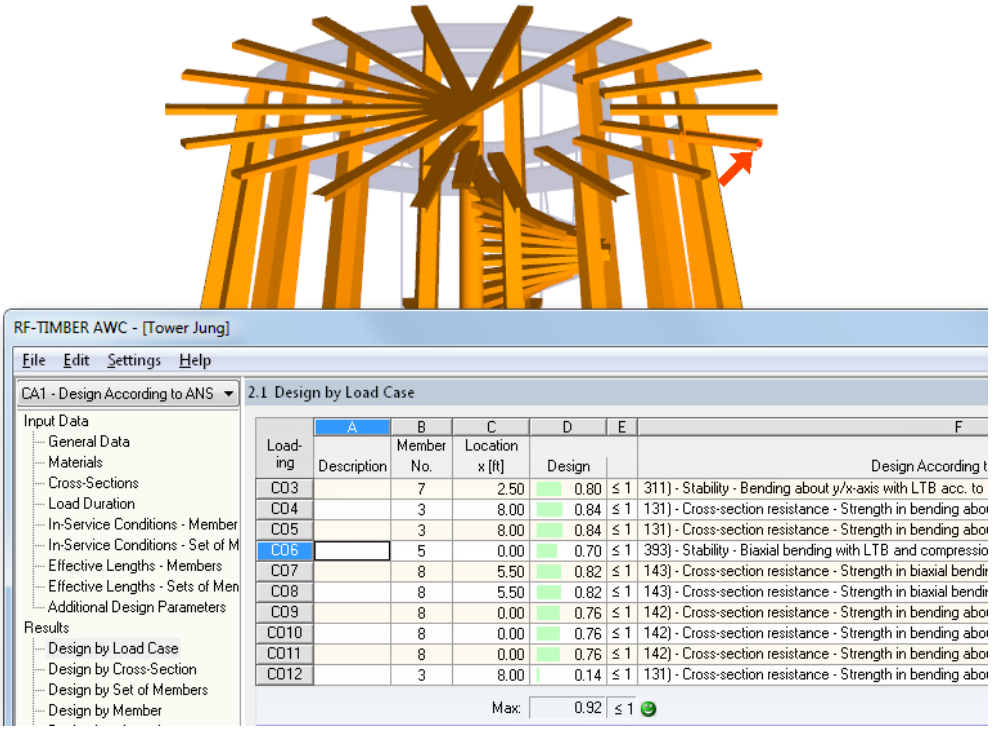
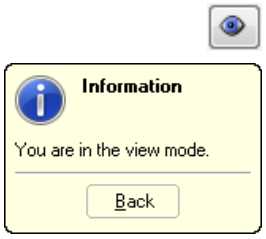


Figure 5.2: Indication of the member and the current *Location x* in the RFEM model



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

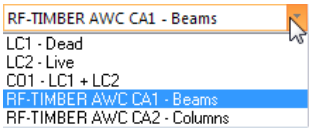
Click [Back] to return to the add-on module RF-TIMBER AWC.

RFEM work window

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

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

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



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

The graphical representation of the results can be set in the *Display* navigator by clicking *Results* → *Members*. The ratios are shown *Two-Colored* by default.

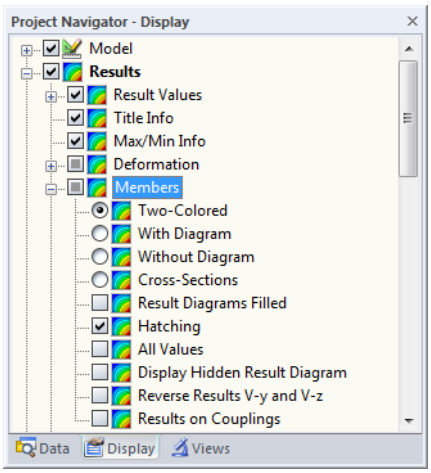


Figure 5.3: *Display* navigator: Results → Members

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

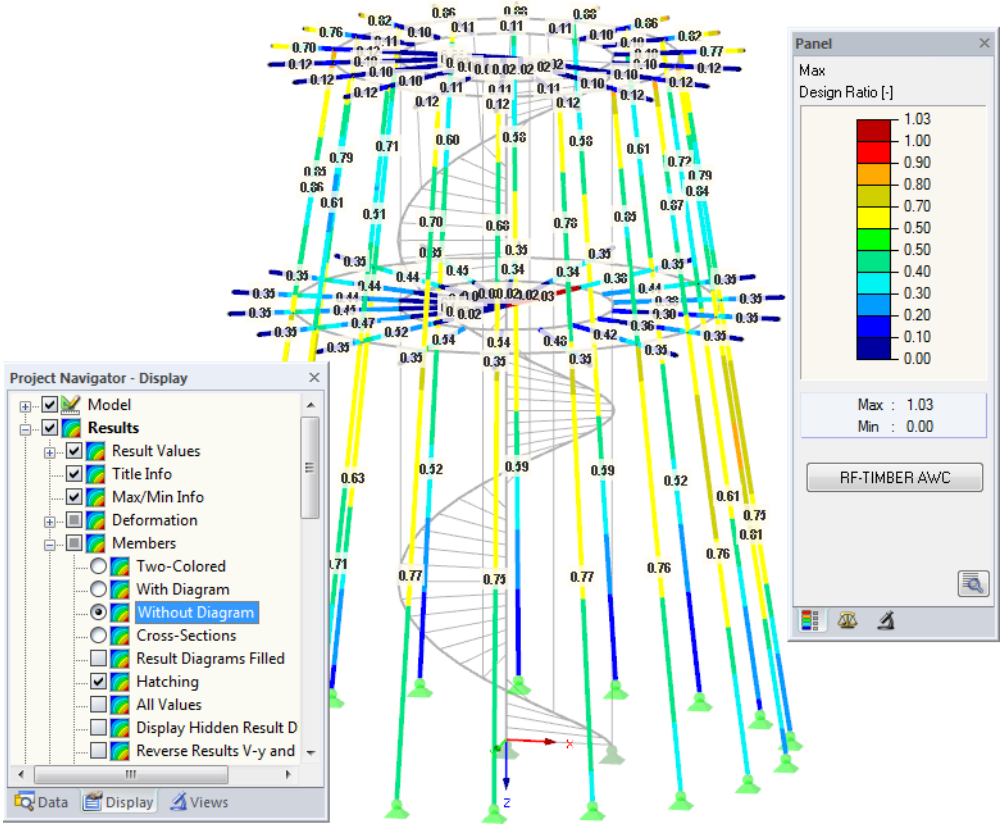


Figure 5.4: Design ratios with display option *Without Diagram*

The graphics of the design results can be transferred to the printout report (see Chapter 6.2, page 60).

RF-TIMBER AWC

To return to the add-on module, click the [RF-TIMBER AWC] panel button.

5.2 Result Diagrams

You can also graphically evaluate the member results in the result diagram.

To do this, select the member (or set of members) in the RF-TIMBER AWC results window by clicking in the table row of the member. Then open the *Result Diagram on Member* dialog box by clicking the button shown on the left. The button is located below the upper results table (see Figure 5.1, page 54).

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

Results → Result Diagrams for Selected Members

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

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

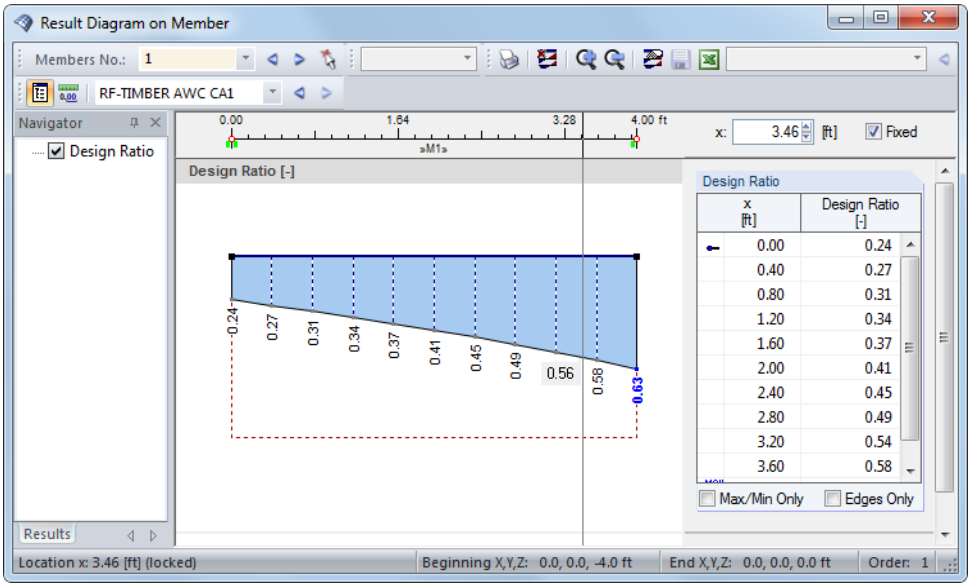
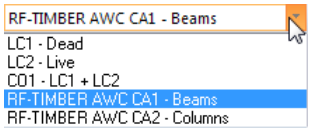


Figure 5.5: Dialog box *Result Diagram on Member*



Use the list in the toolbar above to select the relevant RF-TIMBER AWC design case.

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

5.3 Filter for Results

The RF-TIMBER AWC results windows allow you to sort the results by various criteria. In addition, you can use the filter options for graphical evaluation of the results as described in Chapter 9.9 of the RFEM manual.

You can use the *Visibility* option also for RF-TIMBER AWC (see RFEM manual, Chapter 9.9.1) to filter the members in order to evaluate them.

Filtering designs

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

View → Control Panel (Color scale, Factors, Filter)

or use the toolbar button shown on the left.

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

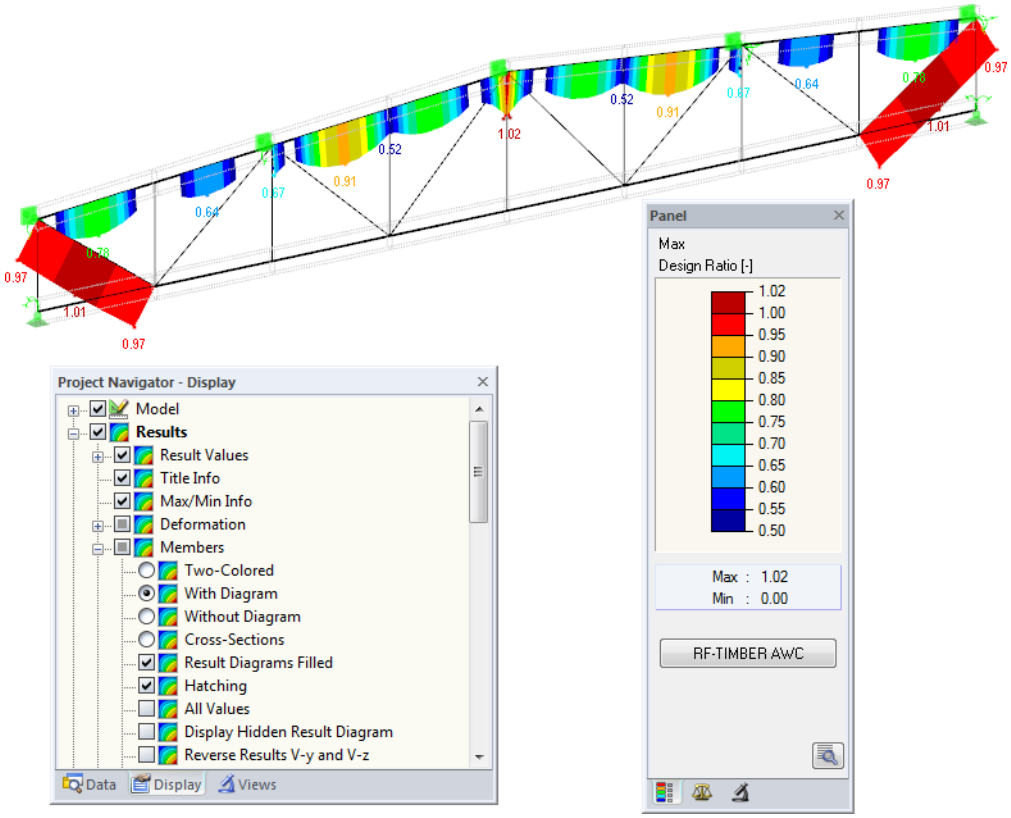


Figure 5.6: Filtering design ratios with adjusted color spectrum

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

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

Filtering members

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

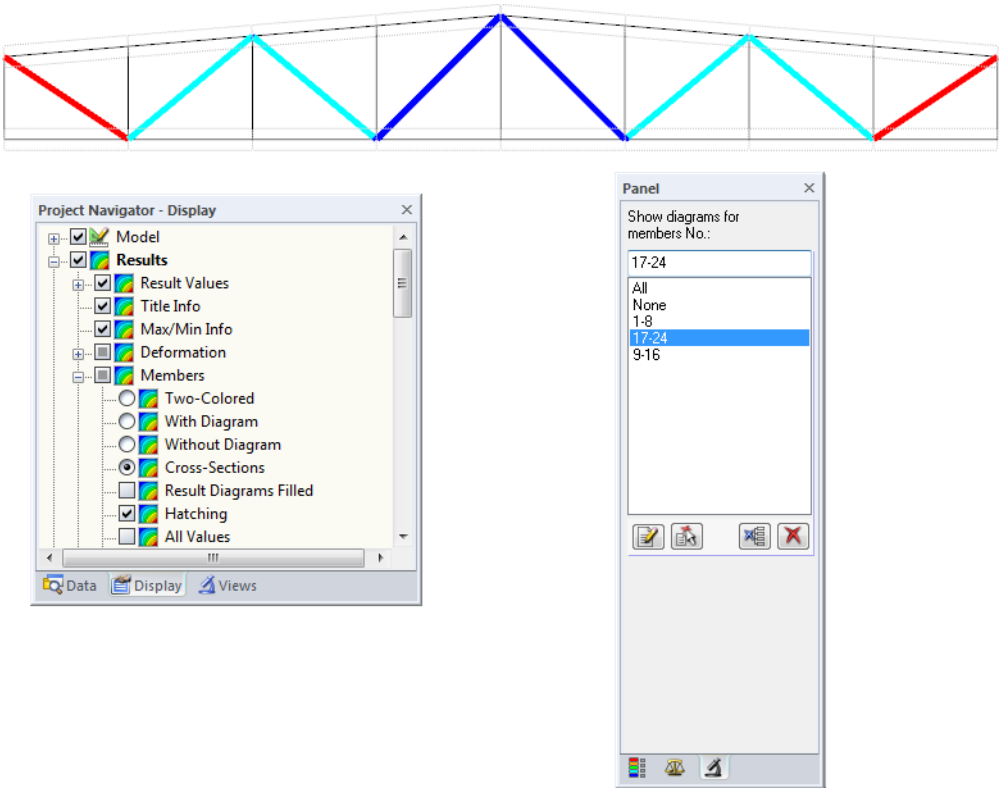


Figure 5.7: Member filter for ratios of diagonals

Unlike the partial view function (*Visibilities*), the model is displayed in the graphic completely. The figure above shows the ratios in the diagonals of a truss girder. The remaining members are displayed in the model but are shown without design ratios.

6. Printout

6.1 Printout Report

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

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

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

6.2 Graphic Printout

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

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

Designs in the RFEM model

To print the currently displayed design ratios, click

File → Print Graphic

or use the toolbar button shown on the left.

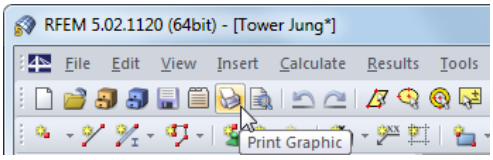


Figure 6.1: Button *Print* in RFEM toolbar

Result diagrams

You can also transfer the *Result Diagram on Member* to the report or print it directly by using the [Print] button.

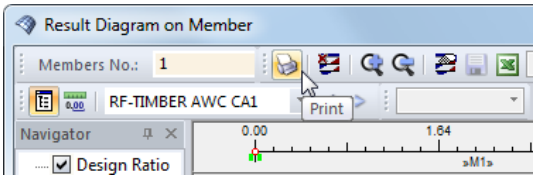


Figure 6.2: Button *Print* in the *Result Diagram on Member*

The *Graphic Printout* dialog box appears (see figure on next page).

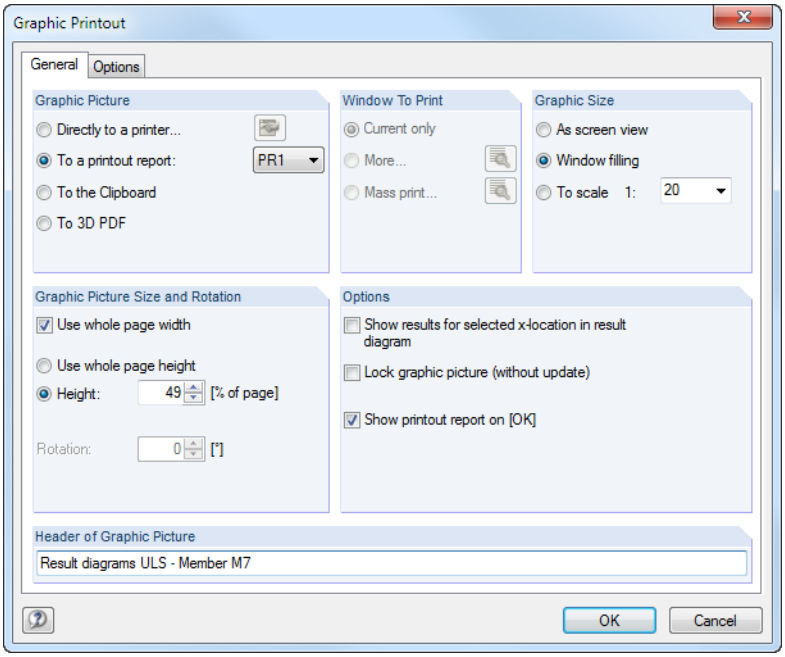
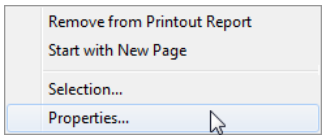


Figure 6.3: Dialog box *Graphic Printout*, tab *General*

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

You can move a graphic anywhere within the printout report by using the drag-and-drop function.



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

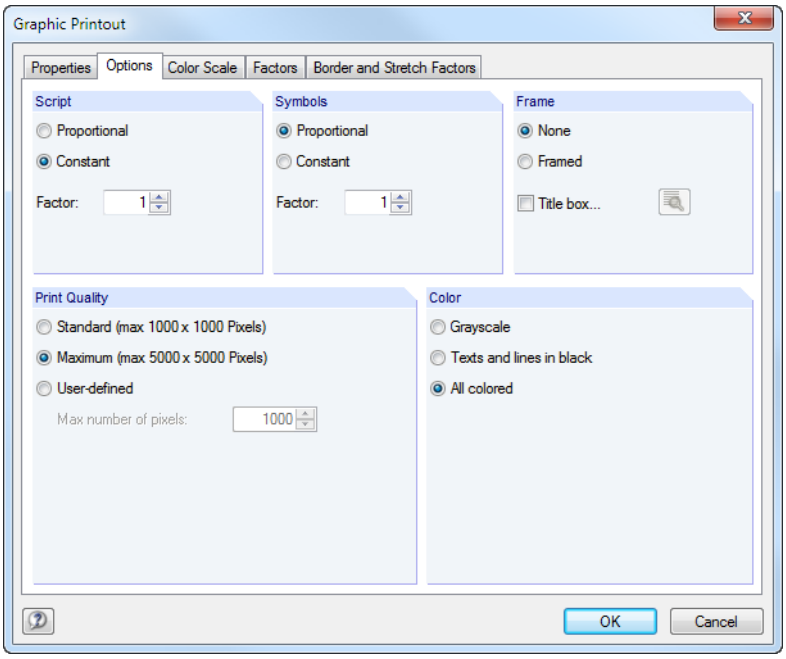


Figure 6.4: Dialog box *Graphic Printout*, tab *Options*

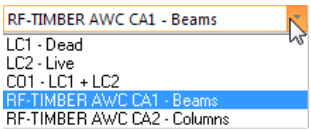
7. General Functions

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

7.1 Design Cases

Design cases allow you to group members for the designs: 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.



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

Create new design case

To create a new design case, use the RF- TIMBER AWC menu and click

File → New Case.

The following dialog box appears:

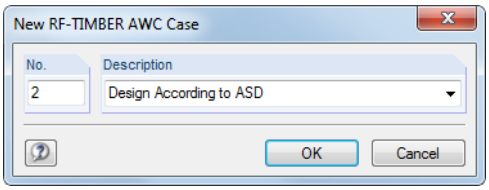


Figure 7.1: Dialog box *New RF-TIMBER AWC-Case*

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

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

Rename design case

To change the description of a design case, use the RF-TIMBER AWC menu and click

File → Rename Case.

The following dialog box appears:

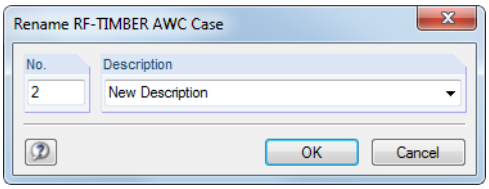


Figure 7.2: Dialog box *Rename RF-TIMBER AWC-Case*

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

Copy design case

To copy the input data of the current design case, use the RF-TIMBER AWC menu

File → Copy Case

The following dialog box appears:

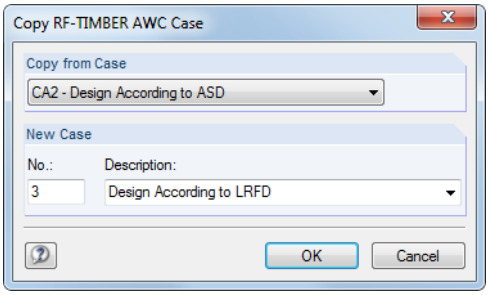


Figure 7.3: Dialog box *Copy RF-TIMBER AWC-Case*

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

Delete design case

To delete design cases, use the RF-TIMBER AWC menu

File → Delete Case

The following dialog box appears:

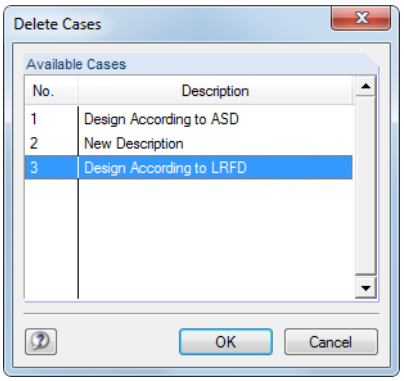
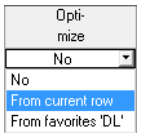


Figure 7.4: Dialog box *Delete Cases*

The design case can be selected in the list *Available Cases*. To delete the selected case, click [OK].

7.2 Cross-Section Optimization



The design module offers you the option to optimize overloaded or little utilized cross-sections. To do this, select in the column D or E of the relevant cross-sections in the 1.3 *Cross-Section* window the option *Yes* (for parametric rectangular or circular sections) or *From current row* (for standardized sections, see Figure 2.19, page 20).

You can also start the cross-section optimization in the results windows by using the context menu.

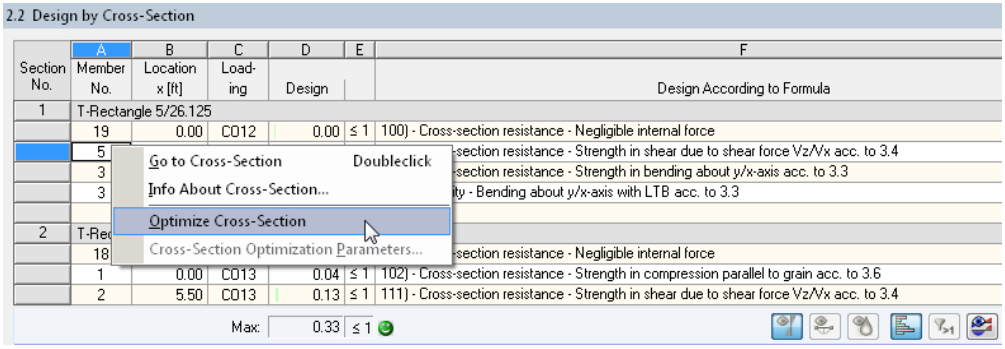


Figure 7.5: Context-menu for cross-section optimization

During the optimization process, the module determines the cross-section that fulfills the analysis requirements in the most optimal way, that is, comes as close as possible to the maximum allowable design ratio specified in the *Details* dialog box (see Figure 3.5, page 42). The required cross-section properties are determined with the internal forces from RFEM. If another cross-section proves to be more favorable, this cross-section is used for the design. Then, the graphic in Window 1.3 shows two cross-sections: the original cross-section from RFEM and the optimized one (see Figure 7.7).

For a parameterized cross-section, the following dialog box appears when you have selected *Yes* from the drop-down list.

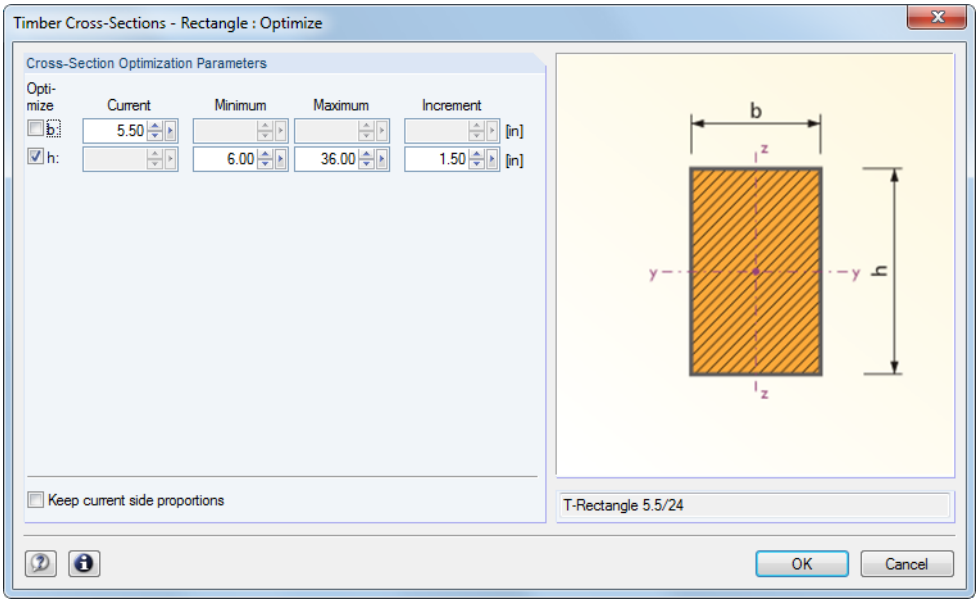


Figure 7.6: Dialog box *Timber Cross-Sections - Rectangle : Optimize*

By selecting the check boxes in the *Optimize* column, you decide which parameter(s) you want to modify. This enables the *Minimum* and *Maximum* columns, where you can specify the upper

and lower limits of the parameter. The *Increment* column determines the interval in which the size of the parameter varies during the optimization process.

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

Please note that the internal forces are not automatically recalculated with the changed cross-sections during the optimization: It is up to you to decide which cross-sections should be transferred to RFEM for recalculation. As a result of optimized cross-sections, internal forces may vary considerably because of the changed stiffnesses in the structural system. Therefore, it is recommended to recalculate the internal forces of the modified cross-section data after the first optimization, and then to optimize the cross-sections once again.

You can export the modified cross-sections to RFEM: Go to the 1.3 *Cross-Sections* window, and then click

Edit → Export All Cross-Sections to RFEM

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

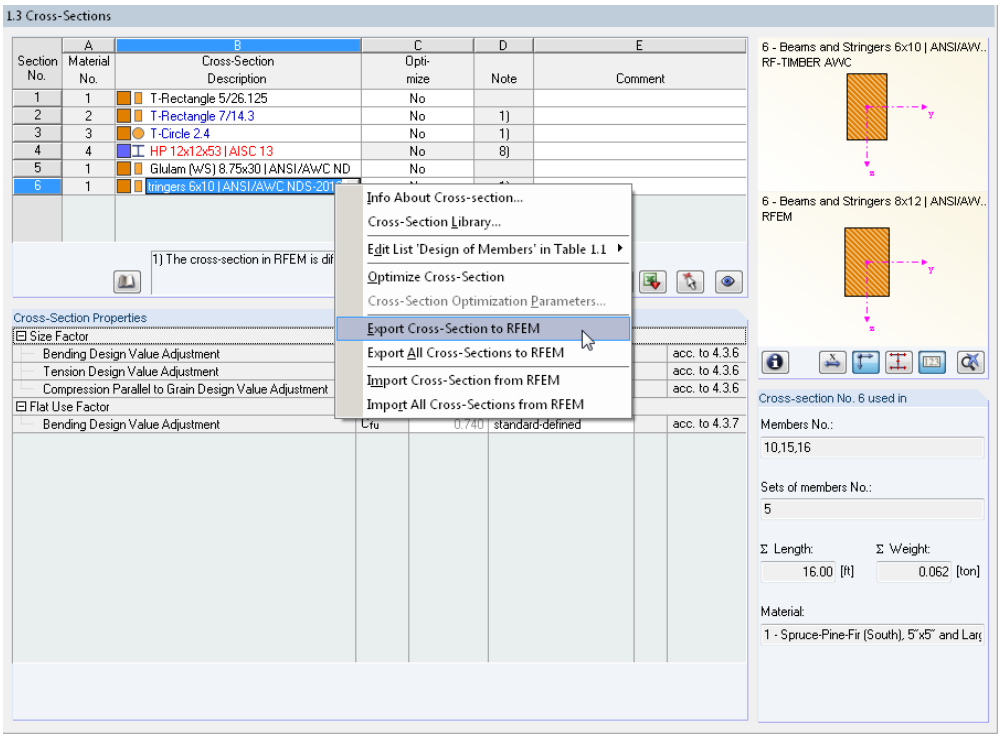


Figure 7.7: Context menu in Window 1.3 *Cross-Sections*

Before the changed materials are transferred to RFEM, a security query appears as to whether the RFEM results should be deleted.

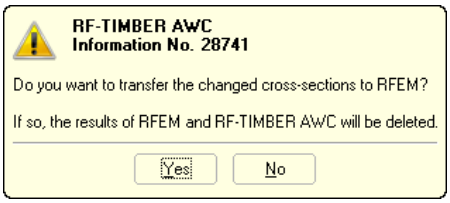


Figure 7.8: Query before transfer of modified cross-sections to RFEM

By confirming the query, and then starting the [Calculation] in the RF-TIMBER AWC module, the RFEM internal forces as well as the designs will be determined in one single calculation run.

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

7.3 Units and Decimal Places

Units and decimal places for RFEM and the add-on modules are managed in one dialog box. To define the units in RF-TIMBER AWC, select menu

Settings → Units and Decimal Places.

The following dialog box appears that is familiar from RFEM. RF- TIMBER AWC is preset in the *Program / Module* list.

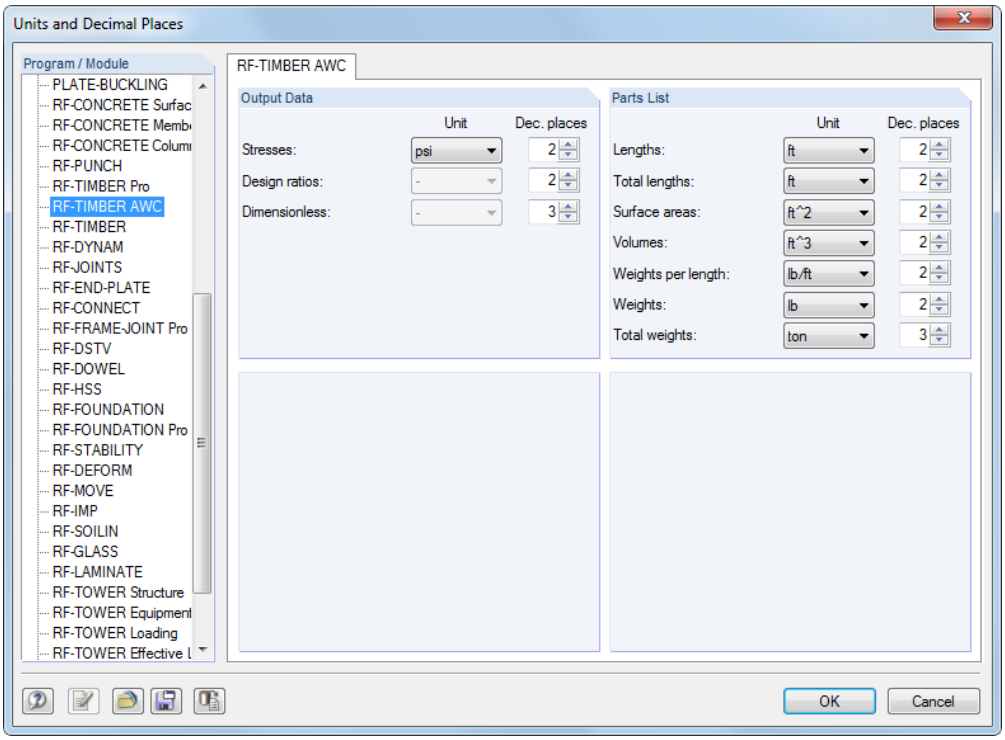


Figure 7.9: Dialog box *Units and Decimal Places*

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

7.4 Data Transfer

7.4.1 Material Export to RFEM

If you have modified the materials in RF-TIMBER AWC for design, you can export the modified materials to RFEM in a similar way as you export cross-sections: Open the 1.2 *Materials* window, and then click

Edit → Export All Materials to RFEM.

You can also export the modified materials to RFEM using the context menu of Window 1.2.

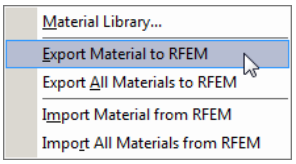


Figure 7.10: Context menu of window 1.2 *Materials*

Before the changed materials are transferred to RFEM, a security query appears as to whether the results of RFEM should be deleted. When you have confirmed the query and then start the [Calculation] in RF-TIMBER AWC, the RFEM internal forces and designs are determined in one single calculation run.

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

7.4.2 Export of Effective Length to RFEM

If you have adjusted the materials in RF-TIMBER AWC for design, you can export the modified materials to RFEM in a similar way as you export cross-sections: Open the 1.7 *Effective Lengths - Members* window, and then select

Edit → Export All Effective Lengths to RFEM

or use the corresponding option on the context menu of Window 1.7.

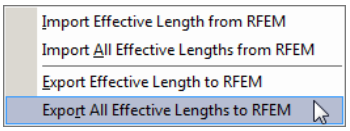


Figure 7.11: Context menu of window 1.7 *Effective Lengths - Members*

Before the modified materials are transferred to RFEM, a security query appears as to whether the results of RFEM should be deleted.

If the modified effective lengths have not been exported to RFEM yet, you can reimport the original effective lengths to the design module by using the options shown in Figure 7.11. Please note, however, that this option is only available in the windows 1.7 *Effective Lengths - Members* and 1.8 *Effective Lengths - Sets of Members*.

7.4.3 Export of Results

The RF-TIMBER AWC results can also be used by other programs.

Clipboard

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

Printout Report

You can print the data of the RF-TIMBER AWC add-on module into the global printout report (see Chapter 6.1, page 60) for export. Then, in the printout report, click

File → Export to RTF

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

Excel / OpenOffice

RF-TIMBER AWC provides a function for the direct data export to MS Excel, OpenOffice.org Calc, or the file format CSV. To open the corresponding dialog box, click

File → Export Tables

The following export dialog box appears.

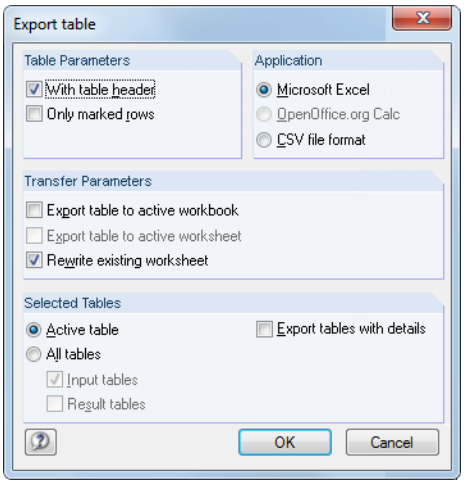


Figure 7.12: Dialog box *Export - MS Excel*

When you have selected the relevant options, you can start the export by clicking [OK]. Excel or OpenOffice will be started automatically, that is, the programs do not have to be opened first.

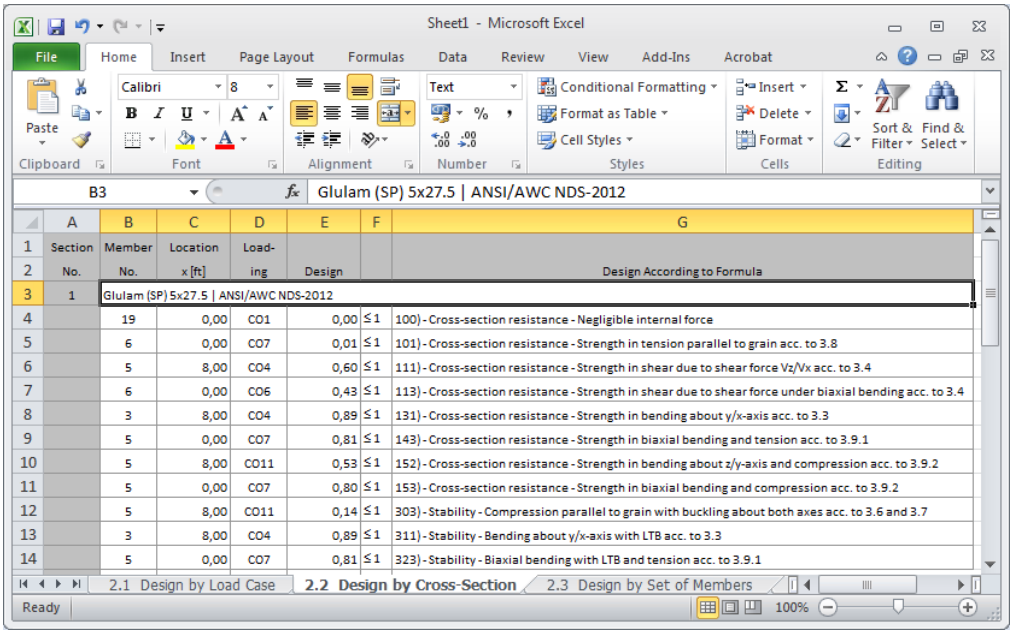


Figure 7.13: Results in *Excel*

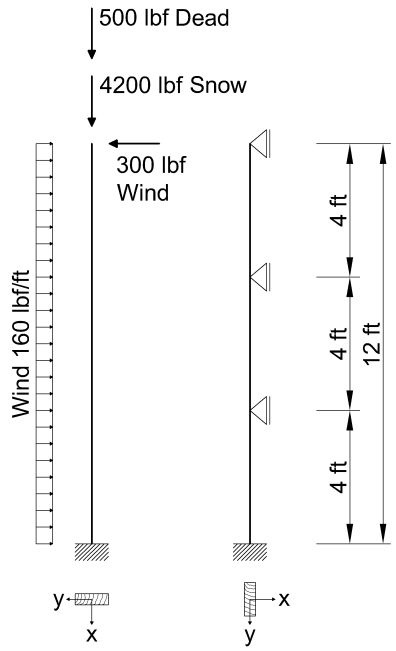
8. Examples

8.1 Beam Column (LRFD Solution)

We perform the design according to ANSI/AWC NDS-2012 for a wood column that is restrained and subjected to compression and bending. It is embedded at the base providing approximate fixity, and it is free to undergo sidesway about the strong axis of bending at the top. There are wet ground conditions. Lateral bracing about the weak direction of bending is provided every 4 ft by wall girts. In case of major axis bending, the concentrated force at the top represents the spring force resulting from the approximate stiffness imparted by the building on a representative post.

The example is described in [4].

8.1.1 System and Loads



Model

Cross-section:	Nominal 4 in by 12 in *(Standard Dressed 3-1/2 in by 11-1/4 in)*
Material:	Southern Pine, No. 1 Dense
Moisture Condition:	Wet
Temperature Condition:	T ≤ 100°F

Load

Load Combination:	1.2D + 1.6S + 0.8W
LC 1 Dead:	500 lbf
LC 2 Snow:	4200 lbf
LC 3 Wind:	160 lbf/ft and 300 lbf

Figure 8.1: System and loads according to [4]

8.1.2 Calculation with RFEM

The system as well as the loads in all load cases is modeled in RFEM as a 3D model. We deactivate the automatic consideration of the self-weight when we create LC1.

We create the considered load combination with relevant factors from defined load cases. Then we calculate the model according to the linear static analysis.

RFEM determines the diagrams of internal forces shown in the following figure.

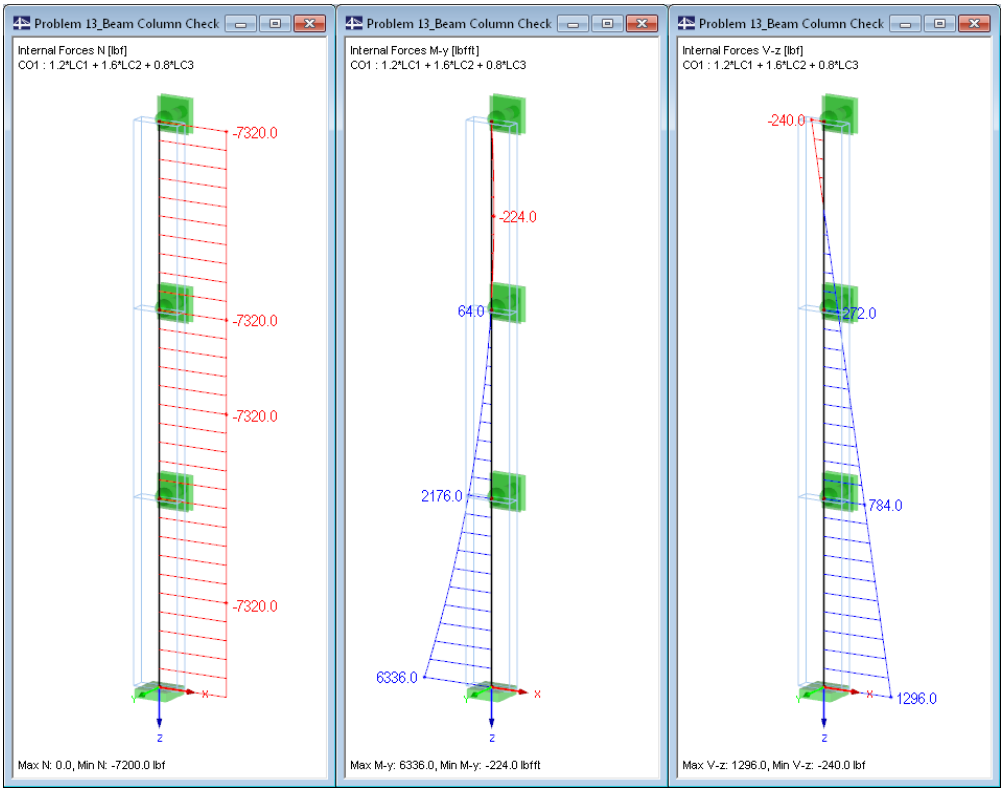


Figure 8.2: Internal forces N, M_y, and V_z

8.1.3 Design with RF-TIMBER AWC

In Window 1.1 *General Data*, we select the result combination **CO1** for the *Ultimate Limit State* design.

We perform the design according to **LRFD**.

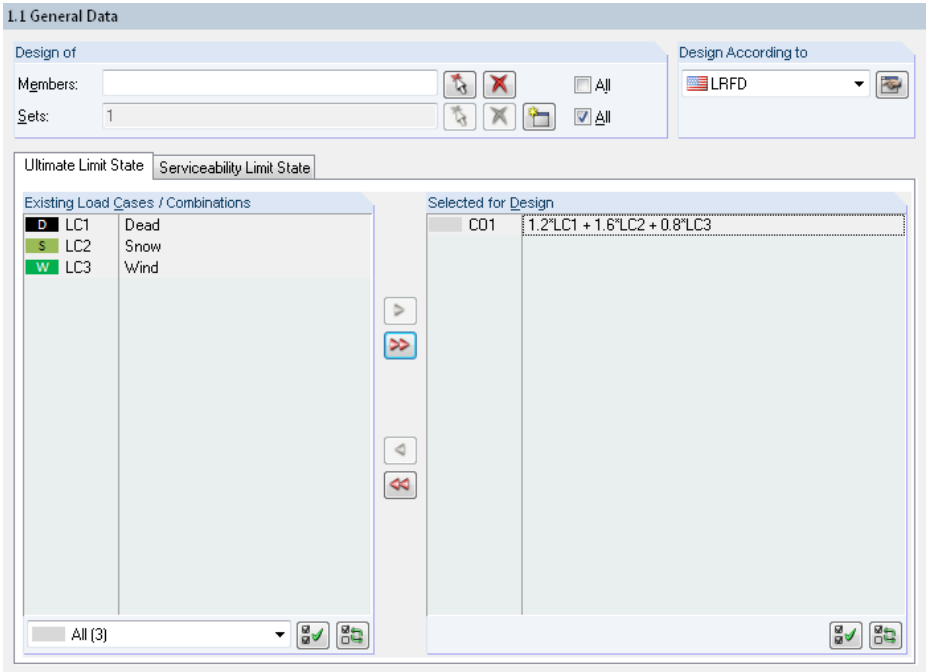


Figure 8.3: Window 1.1 *General Data*

The 1.2 *Materials* window presents the characteristic strengths of the selected material.

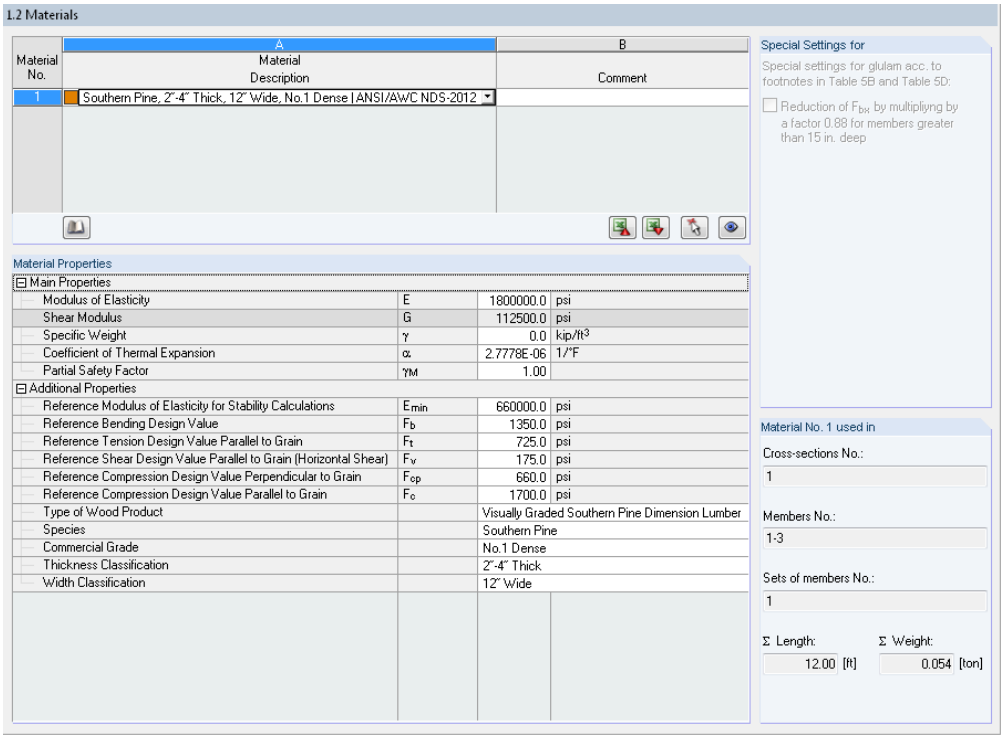


Figure 8.4: Window 1.2 *Materials*

In the 1.3 *Cross-Sections* window, the parameters of the cross-section can be checked.

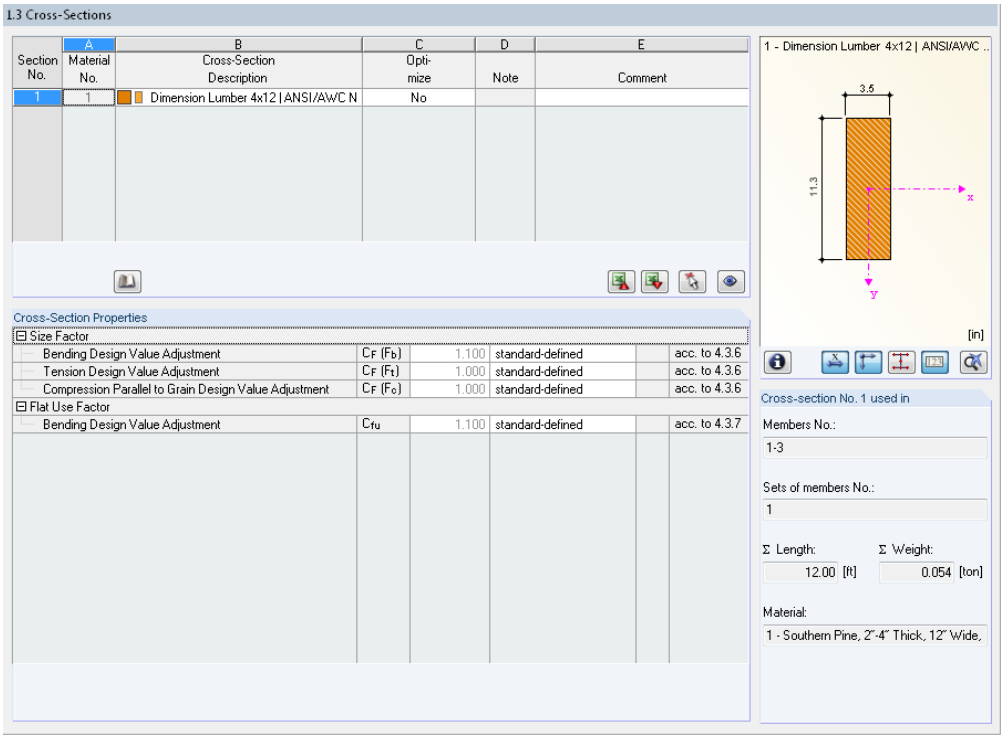


Figure 8.5: Window 1.3 *Cross-Sections*

In Window 1.4 *Load Duration*, we define the load duration. For LRFD it is recommended to assign a **user-defined** load duration also for a load combination because the choice according to shortest load duration in a combination does not always reflect the appropriate value of time effect factor λ according to Table N3 of [1].

1.4 Load Duration

Loading	A Description	B Load Type	C Load Duration	D Factor λ	E Comments
LC1	Dead	Dead	Permanent	0.600	
LC2	Snow	Snow	Two Months	0.800	
LC3	Wind	Wind	Ten Minutes	1.000	
CO1	1.2*LC1 + 1.6*LC2 + 0.8*LC3	-	Two Months	0.800	

Apply time effect factor λ according to:
- ○ Shortest load duration in a combination
- ◉ User-defined settings

Figure 8.6: Window 1.4 *Load Duration*

In Window 1.6 *In-Service Conditions - Set of Members*, we define the moisture and temperature conditions. The factors C_M and C_T are determined as for **wet** service conditions and sustained exposure to elevated temperatures up to 100°F.

1.6 In-Service Conditions - Set of Members

Set No.	A Moisture Service Condition	B Temperature	C Comments
1	Wet	T ≤ 100°F	

Moisture Service Condition

Dry Service Conditions:

Moisture content in service is less than 19% for lumber (less than 16% for glulam)

Wet Service Conditions:

Moisture content in service is 19% or greater for lumber (16% and greater for glulam)

Temperature Effects:

Structural members experience sustained exposure to elevated temperatures up to 100°F

Structural members experience sustained exposure to elevated temperatures between 100°F and 125°F

Structural members experience sustained exposure to elevated temperatures between 125°F and 150°F

☐ Set input for members No.:

☑ All

Figure 8.7: Window 1.6 *In-Service Conditions - Set of Members*

In the 1.8 *Effective Lengths - Sets of Members* window we specify the buckling lengths of the column. The recommended value of buckling length coefficient K_{ex} = **2.1** is taken for the major axis stability calculation.

For the minor axis stability calculation we define directly the buckling length l_{ey} = **4 ft** as the length between lateral bracing girts multiplied by a factor of **1.0**. The effective length for lateral buckling is calculated as unbraced length **4 ft** associated with major axis bending multiplied by factor **2.06**, this equation is defined in footnote 1 in Table 3.3.3 in [1].

1.8 Effective Lengths - Sets of Members

Set No.	A	B	C	D	E	F	G	H	I	J	K
	Buckling	Buckling About Axis x			Buckling About Axis y			Lateral Buckling			
	Possible	Possible	K_{ex}	l_{ex} [ft]	Possible	K_{ey}	l_{ey} [ft]	Possible	l_e Manually	l_e [ft]	Comment
1	☑	☑	2.100	25.20	☑	0.333	4.00	☑	☑	8.24	

Figure 8.8: Window 1.8 *Effective Lengths – Set of Members*

In Window 1.9 *Additional Design Parameters*, the use of further adjustment factors is not required. No member is incised according to 4.3.8 or acts as repetitive according to 4.3.9 in [1] .

1.9 Additional Design Parameters

Member No.	A	B	C	D	E	F
	Adjustment Factors					
	Description	Definition	Symbol	Value [-]	acc. to	Comment
1	Incising Factor	Not Incised	C_i	-	4.3.8	
	Repetitive Factor	Not Repetitive	C_r	-	4.3.9	
2	Incising Factor	Not Incised	C_i	-	4.3.8	
	Repetitive Factor	Not Repetitive	C_r	-	4.3.9	
3	Incising Factor	Not Incised	C_i	-	4.3.8	
	Repetitive Factor	Not Repetitive	C_r	-	4.3.9	

Set input for members No.: ☑ All Material Category: Sawn Lumber

Figure 8.9: Window 1.9 *Additional Design Parameters*

We start the calculation by clicking the [Calculation] button.

After the calculation, the governing design is presented in the 2.1 *Design by Load Case* window.

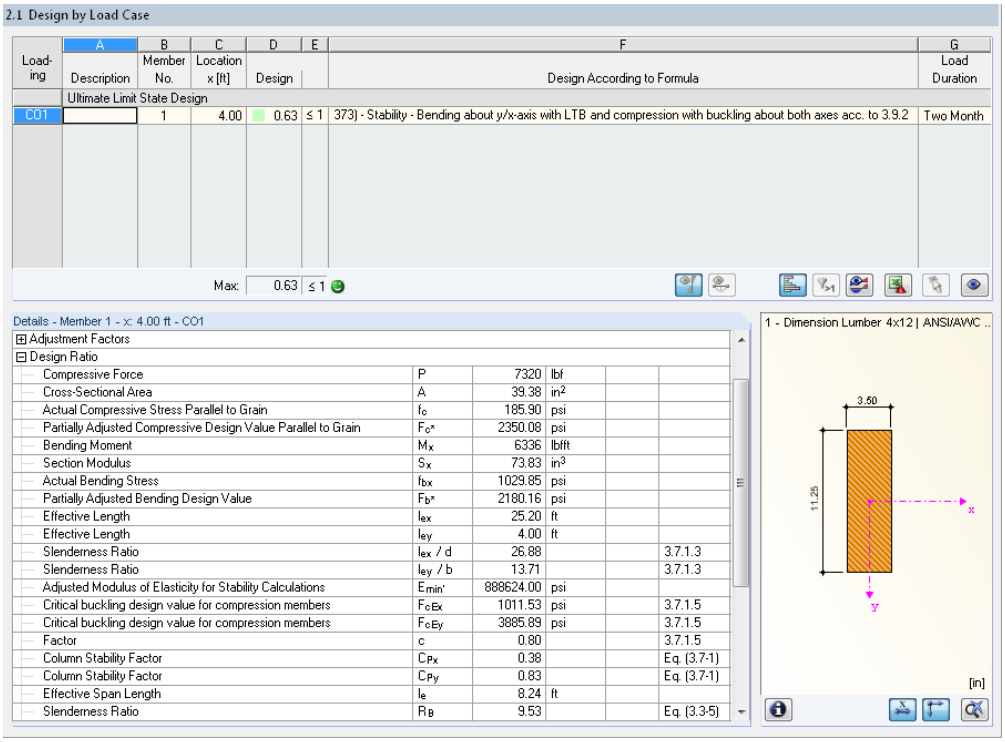


Figure 8.10: Window 2.1 *Design by Load Case*

The *Details* displayed in the lower part of the window correspond to the designs in [4].

The column capacities, which are modified by adjustment factors, are calculated without consideration of stability factors. This calculation is done before the calculation of the design ratio.

Partially Adjusted Compression Design Value

$$F_c^* = \lambda \times K_F \times \Phi \times F_c \times C_M \times C_t \times C_F$$
$$F_c^* = 0.8 \times 2.4 \times 0.9 \times 1700 \times 0.8 \times 1.0 \times 1.0$$
$$F_c^* = 2350.08 \text{ psi}$$

Partially Adjusted Bending Design Value

$$F_b^* = \lambda \times K_F \times \Phi \times F_b \times C_M \times C_t \times C_F$$
$$F_b^* = 0.8 \times 2.54 \times 0.85 \times 1350 \times 0.85 \times 1.0 \times 1.1$$
$$F_b^* = 2180.16 \text{ psi}$$

Adjusted Modulus of Elasticity for Stability Calculations

$$E_{min}' = K_F \times \Phi \times E_{min} \times C_M \times C_t$$
$$E_{min}' = 1.76 \times 0.85 \times 660000 \times 0.9 \times 1.0$$
$$E_{min}' = 888624 \text{ psi}$$

Adjusted Shear Design Value

$$F_v' = \lambda \times K_F \times \Phi \times F_v \times C_M \times C_t$$
$$F_v' = 0.8 \times 2.88 \times 0.75 \times 175 \times 0.97 \times 1.0$$
$$F_v' = 293.33 \text{ psi}$$

The stress analysis is performed as follows.

Actual Compressive Stress Parallel to Grain

$$f_c = \frac{P}{A} = \frac{7320\ \text{lbf}}{39.38\ \text{in}^2} = 185.88\ \text{psi}$$

Actual Bending Stress

$$f_{bx} = \frac{M_x}{S_x} = \frac{6336 \times 12\ \text{lbf.in}}{73.83\ \text{in}^3} = 1029.83\ \text{psi}$$

Actual Shear Stress Parallel to Grain

$$f_v = \frac{V_x \times Q_x}{I_x \times b} = \frac{1296\ \text{lbf} \times 55.37\ \text{in}^3}{415.28\ \text{in}^4 \times 3.5\ \text{in}} = 49.37\ \text{psi}$$

The compressive design stress must be adjusted also by the column stability factor C_P. This factor depends on the critical buckling stress for compression which reflects the member slenderness of compression members.

The total axial capacity for the major axis is calculated as follows.

Slenderness Ratio

$$\frac{l_{ex}}{d} = \frac{302.40\ \text{in}}{11.25\ \text{in}} = 26.88 \le 50$$

Critical Buckling Design Value for Compression Members

$$F_{cEx} = 0.822 \times \frac{E_{min}'}{\left(\frac{l_{ex}}{d}\right)^2} = 0.822 \times \frac{888624}{26.88^2} = 1010.95\ \text{psi}$$

Column Stability Factor

$$C_{Px} = \frac{1 + (F_{cEx}/F_c^*)}{2 \times c} - \sqrt{\left[\frac{1 + (F_{cEx}/F_c^*)}{2 \times c}\right]^2 - \frac{F_{cEx}/F_c^*}{c}}$$

$$C_{Px} = \frac{1 + (1010.95/2350.08)}{2 \times 0.8} - \sqrt{\left[\frac{1 + (1010.95/2350.08)}{2 \times 0.8}\right]^2 - \frac{1010.95/2350.08}{0.8}}$$

$$C_{Px} = 0.383$$

Adjusted Compressive Design Value Parallel to Grain

$$F_{cx}' = F_c^* \times C_{px} = 2350.08 \times 0.383 = 900.08\ \text{psi}$$

The total axial capacity for the minor axis is calculated in the same way.

Slenderness Ratio

$$\frac{l_{ey}}{b} = \frac{48.00\text{ in}}{3.5\text{ in}} = 13.71 \leq 50$$

Critical Buckling Design Value for Compression Members

$$F_{cEy} = 0.822 \times \frac{E_{min}'}{\left(\frac{l_{ey}}{b}\right)^2} = 0.822 \times \frac{888624}{13.71^2} = 3886.11\text{psi}$$

Column Stability Factor

$$C_{Py} = \frac{1+\left(F_{cEy}/F_c^*\right)}{2\times c} - \sqrt{\left[\frac{1+\left(F_{cEy}/F_c^*\right)}{2\times c}\right]^2 - \frac{F_{cEy}/F_c^*}{c}}$$

$$C_{Py} = \frac{1+\left(3886.11/2350.08\right)}{2\times 0.8} - \sqrt{\left[\frac{1+\left(3886.11/2350.08\right)}{2\times 0.8}\right]^2 - \frac{3886.11/2350.08}{0.8}}$$

$$C_{Py} = 0.832$$

Adjusted Compressive Design Value Parallel to Grain

$$F_{cy}' = F_c^* \times C_{py} = 2350.08 \times 0.832 = 1955.27\text{ psi}$$

The bending design stress must also be adjusted by the beam stability factor C_L. This factor depends on the critical buckling stress for bending which reflects the member slenderness of bending members.

The total flexural capacity is calculated as follows.

Slenderness Ratio

$$R_B = \sqrt{\frac{l_e \times d}{b^2}} = \sqrt{\frac{(8.24\times 12)\times 11.25}{3.50^2}} = 9.53$$

Critical Buckling Design Value for Bending Members

$$F_{bE} = \frac{1.20\times E_{min}'}{R_B{}^2} = \frac{1.20\times 888624}{9.53^2} = 11741.23\text{ psi}$$

Beam Stability Factor

$$C_L = \frac{1+\left(F_{bE}/F_b^*\right)}{1.9} - \sqrt{\left[\frac{1+\left(F_{bE}/F_b^*\right)}{1.9}\right]^2 - \frac{F_{bE}/F_b^*}{0.95}}$$

$$C_L = \frac{1+\left(11741.23/2180.16\right)}{1.9} - \sqrt{\left[\frac{1+\left(11741.23/2180.16\right)}{1.9}\right]^2 - \frac{11741.23/2180.16}{0.95}}$$

$$C_L = 0.989$$

Adjusted Bending Design Value:

$$F_{bx}' = F_b^* \times C_L = 2180.16 \times 0.989 = 2156.18\text{ psi}$$

Critical Design Values Check

Before combined bending and axial compression proportions are verified, critical design stresses must be compared according to Equation (3.9-4) and the next formulas mentioned in [1], Clause 3.9.2.

$$\frac{f_c}{F_{cEx}} = \frac{185.88}{1010.95} = 0.18 \le 1.00$$

$$\frac{f_c}{F_{cEy}} = \frac{185.88}{3886.11} = 0.05 \le 1.00$$

$$\frac{f_b}{F_{bE}} = \frac{1029.83}{11741.23} = 0.09 \le 1.00$$

$$\frac{f_c}{F_{cEy}} + \left(\frac{f_b}{F_{bE}}\right)^2 = \frac{185.88}{3886.11} + \left(\frac{1029.83}{11741.23}\right)^2 = 0.06 \le 1.00$$

Combined Bending and Axial Compression Design

Design of combined bending and axial compression according to [1], Equation (3.9-3):

Design 1 (buckling about x-x axis)

$$\left[\frac{f_c}{F_{cx}'}\right]^2 + \frac{f_{bx}}{F_{bx}' \times \left[1 - \left(f_c / F_{cEx}\right)\right]} \le 1.00$$

$$\left[\frac{185.88}{900.08}\right]^2 + \frac{1029.83}{2156.18 \times \left[1 - \left(185.88/1010.95\right)\right]} = 0.63 \le 1.00$$

Design 2 (buckling about y-y axis)

$$\left[\frac{f_c}{F_{cy}'}\right]^2 + \frac{f_{bx}}{F_{bx}' \times \left[1 - \left(f_c / F_{cEx}\right)\right]} \le 1.00$$

$$\left[\frac{185.88}{1955.27}\right]^2 + \frac{1029.83}{2156.18 \times \left[1 - \left(185.88/1010.95\right)\right]} = 0.59 \le 1.00$$

Shear Design

The shear design is performed according to [1], Clause 3.4.1:

Design

$$\frac{f_v}{F_v'} = \frac{49.37}{293.33} = 0.17 \le 1.00$$

8.2 Glued Laminated Beam (ASD Solution)

We perform the design according to ANSI/AWC NDS-2012 for a structural glued laminated roof purlin that is restrained and subjected to biaxial bending. The beam is laterally supported at its ends only, and there are no intermediate lateral supports.

The example is described in [4].

8.2.1 System and Loads

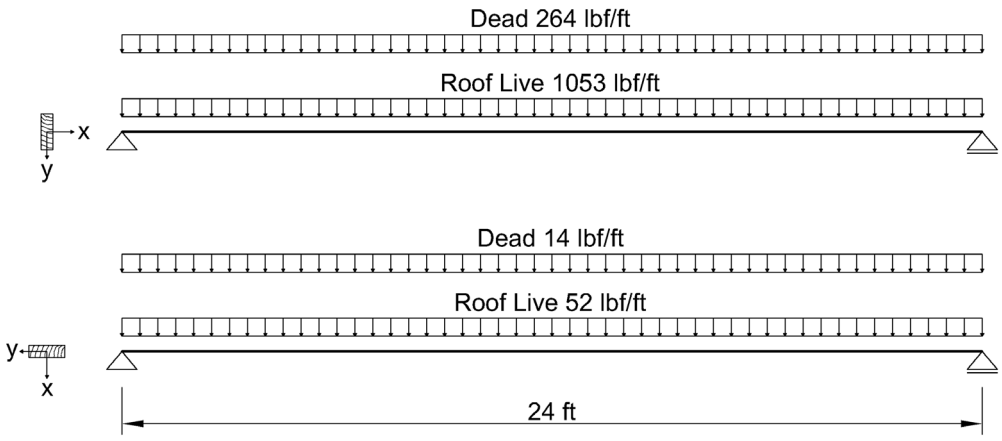


Figure 8.11: System and loads according to [4]

Model

Cross-section:	6-3/4 in by 24 in
Material:	Douglas-fir 24F-V10
Moisture Condition:	Dry
Temperature Condition:	T ≤ 100°F

Loads

Load Combination:		$D + L_r$
LC 1	$Dead_x$:	264 lbf/ft
LC 1	$Dead_y$:	14 lbf/ft
LC 2	$Roof\ Live_x$:	1053 lbf/ft
LC 2	$Roof\ Live_y$:	52 lbf/ft

8.2.2 Calculation with RFEM

The system as well as the loads in all load cases is modeled in RFEM as a 3D model. We deactivate the automatic consideration of the self-weight when we create LC1.

We create the considered load combination with relevant factors from defined load cases. Then we calculate the model according to the linear static analysis.

RFEM determines the diagrams of internal forces shown in the following figure.

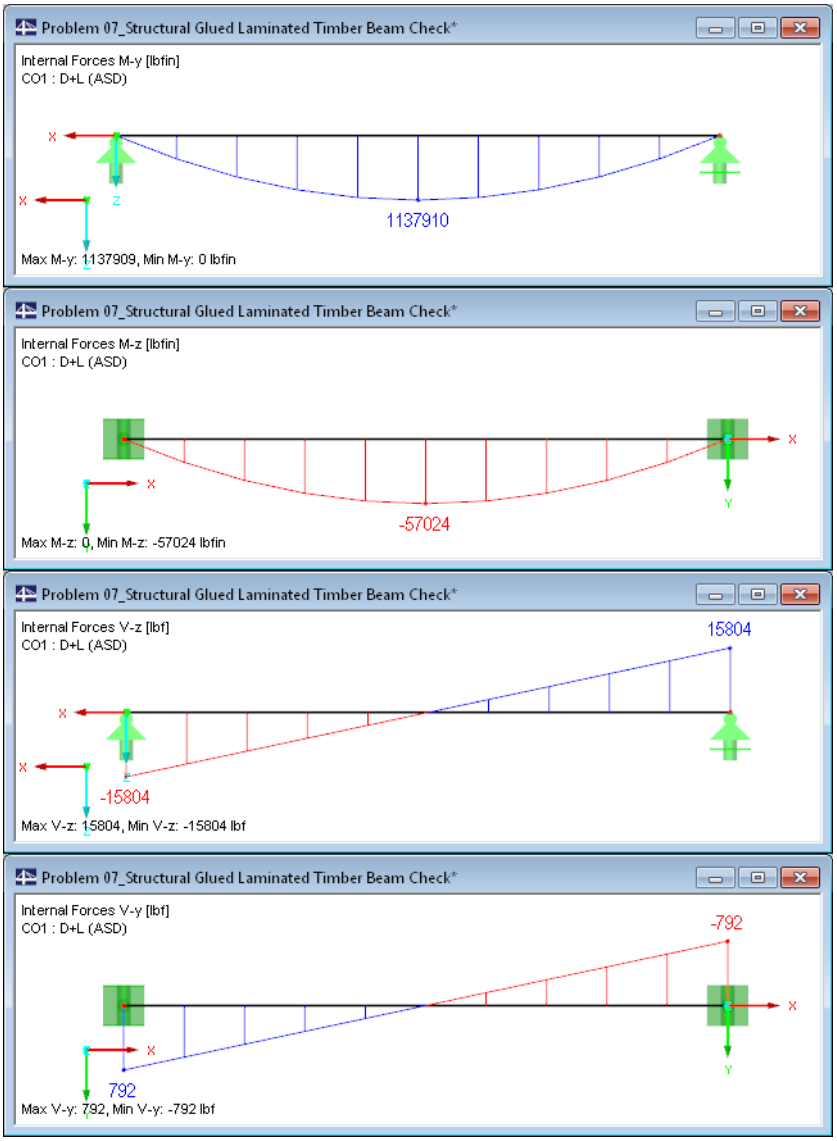


Figure 8.12: Internal forces M_y, M_z, V_z, and V_y

8.2.3 Design with RF-TIMBER AWC

8.2.3.1 Ultimate Limit State Design

In Window 1.1 *General Data*, we select the result combination **CO1** for the *Ultimate Limit State* design.

We perform the design according to **ASD**.

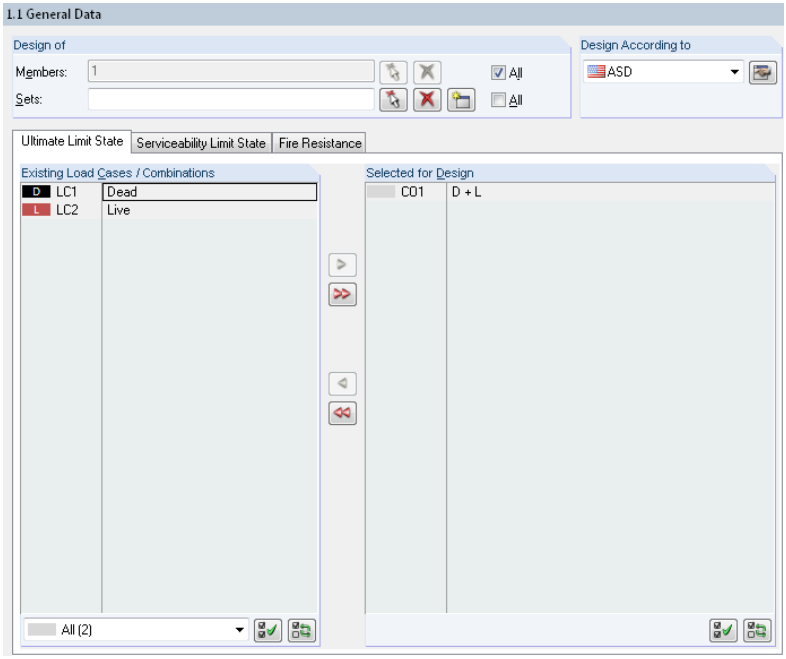


Figure 8.13: Window 1.1 *General Data*

The 1.2 *Materials* window presents the characteristic strengths of the selected material.

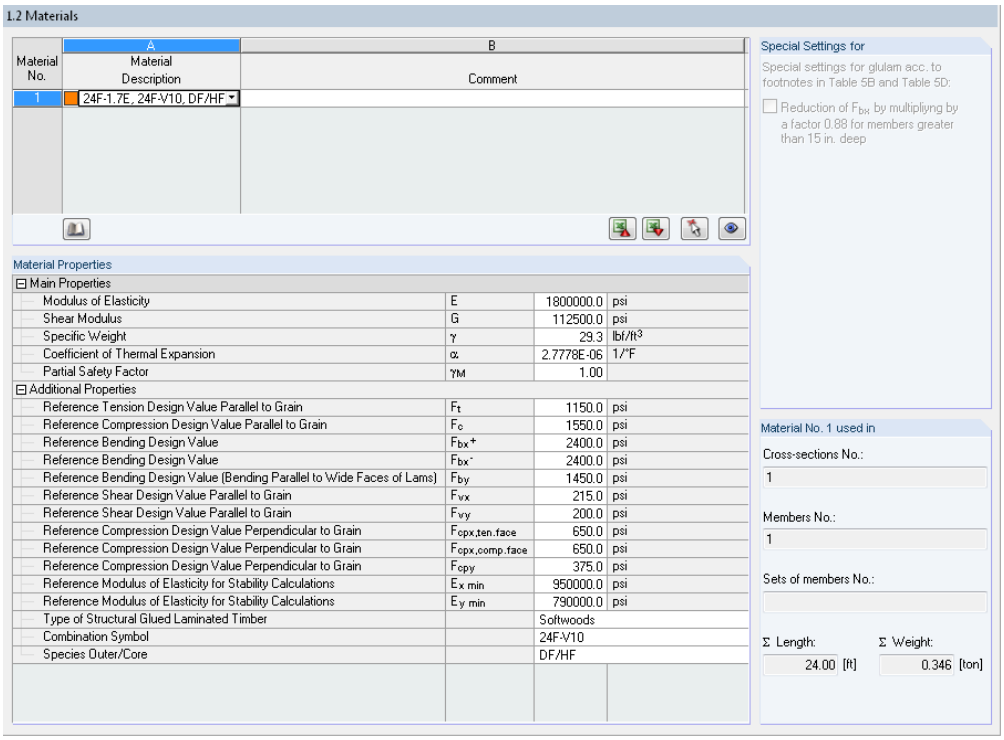


Figure 8.14: Window 1.2 *Materials*

In the 1.3 *Cross-Sections* window, the parameters of the cross-section can be checked.

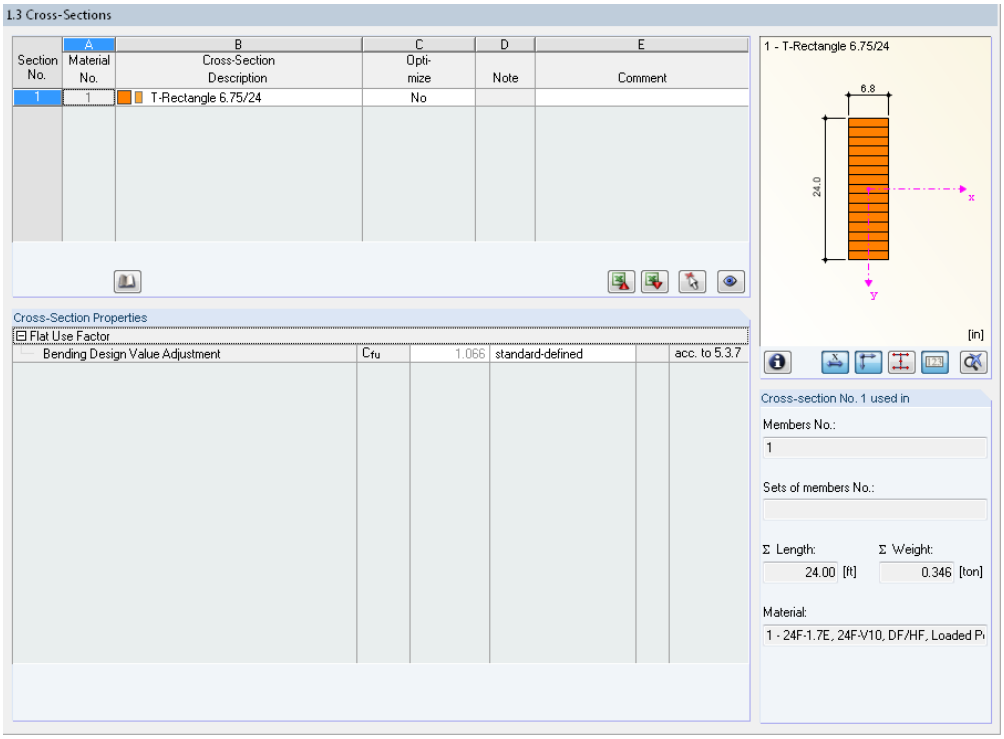


Figure 8.15: Window 1.3 *Cross-Sections*

In Window 1.4 *Load Duration*, we define the load duration. For ASD, the load duration for load combination is assigned according to the shortest load duration included in this combination. The load duration of CO1 is preset as **Seven Days**.

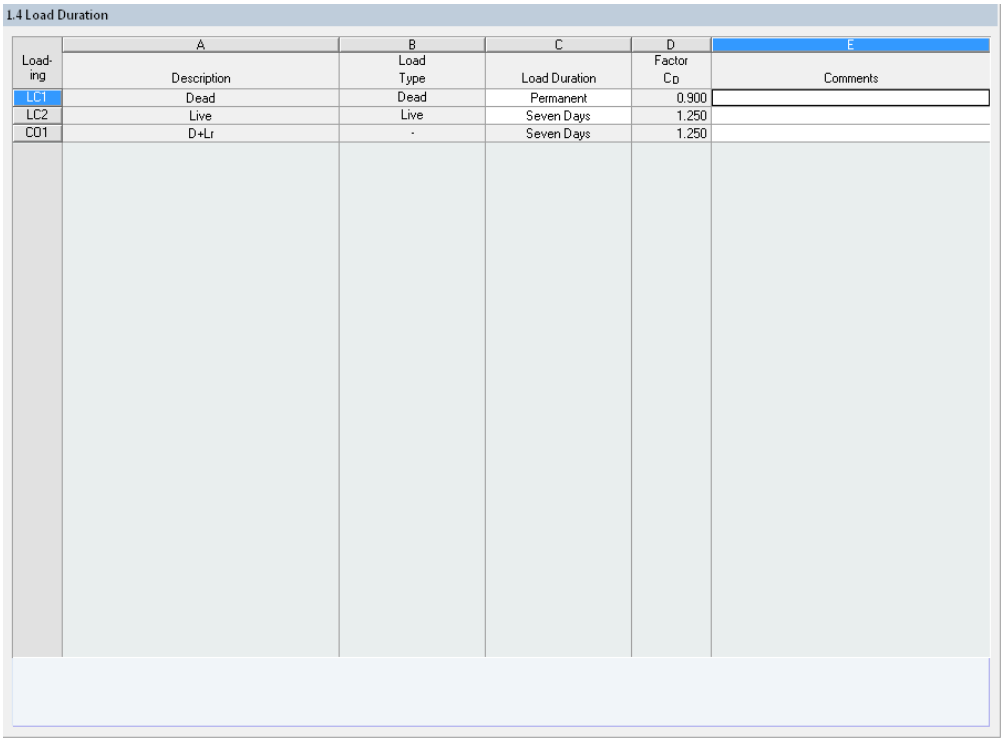


Figure 8.16: Window 1.4 *Load Duration*

In Window 1.5 *In-Service Condition - Members*, we define the moisture and temperature conditions. The factors C_M and C_T are determined for **dry** service conditions and sustained exposure to elevated temperatures up to 100°F.

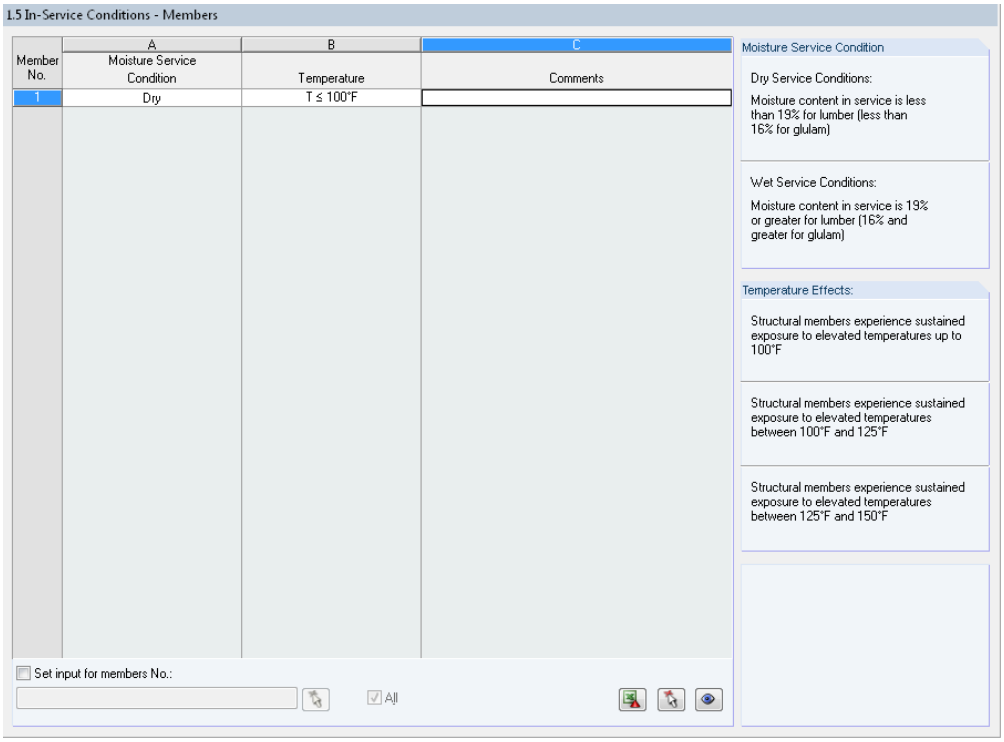


Figure 8.17: Window 1.5 *In-Service Conditions - Members*

In Window 1.7 *Effective Lengths - Members* we specify the buckling lengths. The beam is braced only at the ends. The effective buckling length for lateral-torsional buckling is automatically calculated according to [1] Table 3.3.3 for a single spam beam with uniformly distributed load where ratio of the unbraced length and the depth of the cross-section is higher than seven:

l_e = 1.63 x unbraced length + 3 x depth of cross-section = **45.12 ft**.

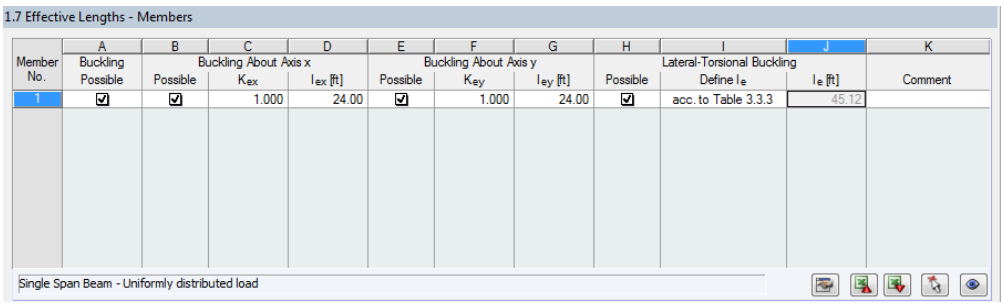


Figure 8.18: Window 1.7 *Effective Lengths - Members*

In Window 1.9 *Additional Design Parameters*, the use of further adjustment factors is not required. There is no shear reduction to be applied.

1.9 Additional Design Parameters

Member No.	A Description	B Adjustment Factors Definition	C Symbol	D Value [-]	E acc. to	F Comment
1	Shear Reduction Factor	No Shear Reduction	C_{vr}	-	5.3.10	
	Shear Edge-Bonded Factor	Edge-Bonded	-	-	NDS Suppl.	

Set input for members No.: All

Material Category: Structural Glued Laminated Timber

Figure 8.19: Window 1.9 *Additional Design Parameters*

Calculation

We start the calculation by clicking the [Calculation] button.

After the calculation, the governing design is presented in the 2.1 *Design by Load Case* window.

2.1 Design by Load Case

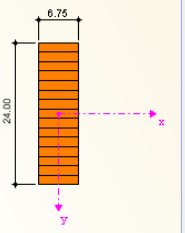
Load-ing	A Description	B Member No.	C Location x [ft]	D Design	E	F Design According to Formula	G Load Duration
	Ultimate Limit State Design						
CO1	D+L (ASD)	1	12.00	0.91	≤ 1	313) - Stability - Biaxial bending with LTB acc. to 3.9	Seven Day

Max: 0.91 ≤ 1

Details - Member 1 - x: 12.00 ft - CO1

Adjustment Factors					
Design Ratio					
Bending Moment	M_x	1137910	lbfin		
Bending Moment	M_y	57024	lbfin		
Section Modulus	S_x	648.0	in^3		
Section Modulus	S_y	182.2	in^3		
Actual Bending Stress	f_{bx}	1756.03	psi		
Actual Bending Stress	f_{by}	312.89	psi		
Partially Adjusted Bending Design Value	F_{bx}^*	3000.00	psi		
Partially Adjusted Bending Design Value	F_{by}^*	1812.50	psi		
Cross-Section Breadth	b	6.75	in		
Cross-Section Depth	d	24.00	in		
Length Between Points of Zero Moments	L	24.00	ft		
Constant	x	10			
Volume Factor	C_V	0.896			Eq. (5.3-1)
Flat Use Factor	C_{fu}	1.066			5.3.7
Effective Span Length	l_e	45.12	ft		
Slenderness Ratio	R_B	16.89			Eq. (3.3-5)
Adjusted Modulus of Elasticity for Stability Calculations	$E_{minyy'}$	790000.00	psi		
Critical buckling design value for bending members	F_{bE}	3323.95	psi		3.3.3.8
Beam Stability Factor	C_L	0.855			Eq. (3.3-6)
Adjusted Bending Design Value	F_{bx}'	2565.81	psi		
Adjusted Bending Design Value	F_{by}'	1932.16	psi		
Design (Critical Bending Design Value Check)	f_{bx} / F_{bE}	0.53			3.9.2
Design Ratio	η	0.91		≤ 1	Eq. (3.9-3)

1 - T-Rectangle 6.75/24



[in]

Figure 8.20: Window 2.1 *Design by Load Case*

The *Details* displayed in the lower part of the window correspond to the designs in [4].

The beam capacities, which are modified by adjustment factors, are calculated without consideration of stability factors. This calculation is done before the calculation of the design ratio.

Partially Adjusted Bending Design Values

$$F_{bx}^* = F_{bx} \times C_M \times C_t \times C_D$$
$$F_{bx}^* = 2400 \times 1.0 \times 1.0 \times 1.25$$
$$F_{bx}^* = 3000.00 \text{ psi}$$

$$F_{by}^* = F_{by} \times C_M \times C_t \times C_D$$
$$F_{by}^* = 1450 \times 1.0 \times 1.0 \times 1.25$$
$$F_{by}^* = 1812.50 \text{ psi}$$

Adjusted Modulus of Elasticity for Stability Calculations

$$E_{min}' = E_{min} \times C_M \times C_t$$
$$E_{min}' = 790000 \times 1.0 \times 1.0$$
$$E_{min}' = 790000 \text{ psi}$$

Adjusted Shear Design Values

$$F_{vx}' = F_{vx} \times C_M \times C_t \times C_D$$
$$F_{vx}' = 215 \times 1.0 \times 1.0 \times 1.25$$
$$F_{vx}' = 268.75 \text{ psi}$$

$$F_{vy}' = F_{vy} \times C_M \times C_t \times C_D$$
$$F_{vy}' = 200 \times 1.0 \times 1.0 \times 1.25$$
$$F_{vy}' = 250.00 \text{ psi}$$

The stress analysis is performed as follows.

Actual Bending Stresses

$$f_{bx} = \frac{M_x}{S_x} = \frac{1137910 \text{ lbf.in}}{648.00 \text{ in}^3} = 1756.03 \text{ psi}$$

$$f_{by} = \frac{M_y}{S_y} = \frac{57024 \text{ lbf.in}}{182.25 \text{ in}^3} = 312.89 \text{ psi}$$

Actual Shear Stress Parallel to Grain

$$f_{vx} = \frac{V_x \times Q_x}{I_x \times b} = \frac{15804 \text{ lbf} \times 486.00 \text{ in}^3}{7776.00 \text{ in}^4 \times 6.75 \text{ in}} = 146.33 \text{ psi}$$

$$f_{vy} = \frac{V_y \times Q_y}{I_y \times b} = \frac{792 \text{ lbf} \times 136.69 \text{ in}^3}{615.09 \text{ in}^4 \times 24.00 \text{ in}} = 7.33 \text{ psi}$$

The bending design stress must be adjusted also by the lesser of the beam stability factor, C_L, and volume factor, C_V.

The beam stability factor depends on the critical buckling stress for bending which reflects the member slenderness of bending members.

Slenderness Ratio

$$R_B = \sqrt{\frac{l_e \times d}{b^2}} = \sqrt{\frac{(45.12 \times 12) \times 24.00}{6.75^2}} = 16.89$$

Critical Buckling Design Value for Bending Members

$$F_{bE} = \frac{1.20 \times E_{min}'}{R_B{}^2} = \frac{1.20 \times 790000 \text{ psi}}{16.89^2} = 3323.93 \text{ psi}$$

Beam Stability Factor

$$C_L = \frac{1 + F_{bE}}{1.9} - \sqrt{\left[\frac{1 + (F_{bE}/F_b{}^*)}{1.9}\right]^2 - \frac{F_{bE}/F_b{}^*}{0.95}}$$

$$C_L = \frac{1 + (3323.93/3000.00)}{1.9} - \sqrt{\left[\frac{1 + (3323.93/3000.00)}{1.9}\right]^2 - \frac{3323.93/3000.00}{0.95}}$$

$$C_L = 0.855$$

The volume factor depends on the cross-section dimensions [in] and the length of the bending member between points of zero moment [ft].

Volume Factor

$$C_V = \left(\frac{21}{L}\right)^{1/x} \times \left(\frac{12}{d}\right)^{1/x} \times \left(\frac{5.125}{b}\right)^{1/x}$$

$$C_V = \left(\frac{21}{24}\right)^{1/10} \times \left(\frac{12}{24}\right)^{1/10} \times \left(\frac{5.125}{6.75}\right)^{1/10}$$

$$C_V = 0.896$$

The total flexural capacity is calculated as follows.

Adjusted Bending Design Values:

$$F_{bx}' = F_{bx}{}^* \times \min(C_L; C_V) = 3000.00 \times \min(0.855; 0.896) = 2565.00 \text{ psi}$$

$$F_{by}' = F_{by}{}^* \times C_{fu} = 1812.50 \times 1.07 = 1939.38 \text{ psi}$$

Critical Design Values Check

Before biaxial bending proportions are verified, critical design stresses must be compared according to formulas mentioned in [1] (Chapter 3.9.2).

$$\frac{f_{bx}}{F_{bE}} = \frac{1756.03}{3323.93} = 0.53 \le 1.00$$

Biaxial Bending Design

The design of biaxial bending according to [1], Equation (3.9-3) is as follows:

$$\frac{f_{bx}}{F_{bx}'} + \frac{f_{by}}{F_{by}' \times \left[1 - \left(\frac{f_{bx}}{F_{bE}}\right)^2\right]} \le 1.00$$

$$\frac{1756.03}{2565.00} + \frac{312.89}{1939.38 \times \left[1 - \left(\frac{1756.03}{3323.93}\right)^2\right]} = 0.91 \le 1.00$$

Shear Design

The design of shear is performed according to [1], Clause 3.4.1:

Design 1 (Shear due to shear force V_x)

$$\frac{f_{vx}}{F_{vx}'} = \frac{146.33}{268.75} = 0.54 \leq 1.00$$

Design 2 (Shear due to shear force V_y)

$$\frac{f_{vy}}{F_{vy}'} = \frac{7.33}{250.00} = 0.03 \leq 1.00$$

8.2.3.2 Serviceability Limit State Design

We check the deflection limit for the unfactored live load.

In the ***Serviceability Limit State*** tab of the 1.1 *General Data* window, we select the load case **LC2** *Live* for the design.

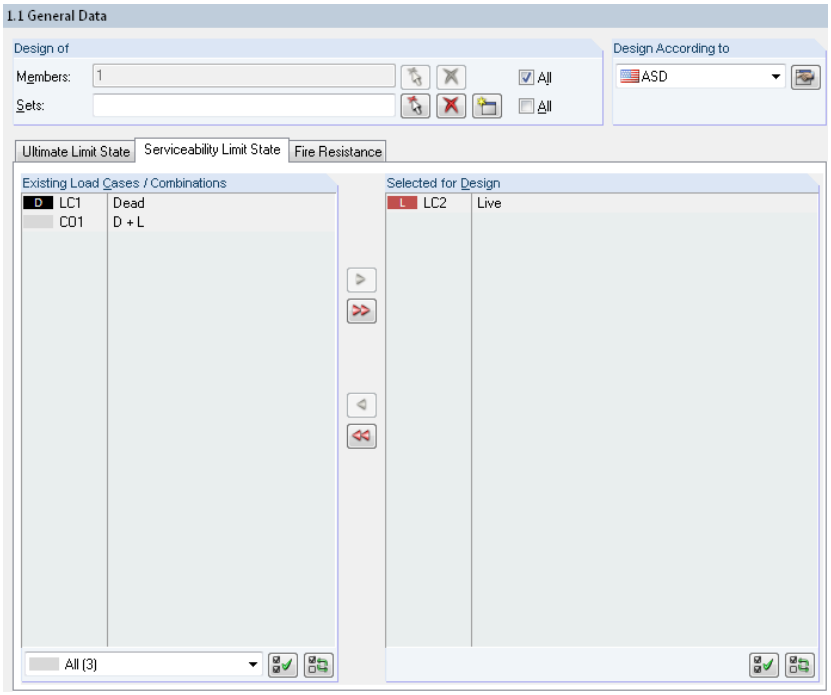
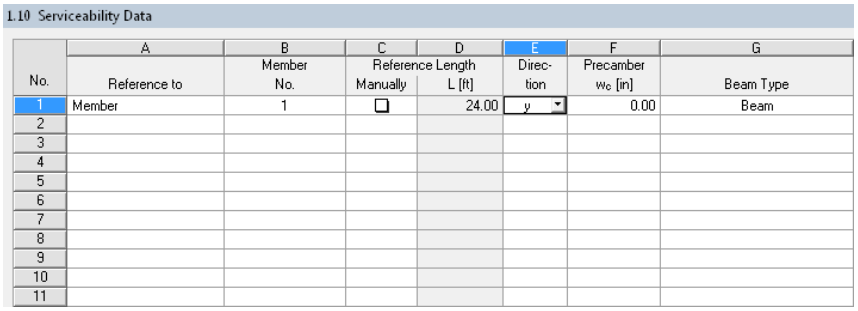


Figure 8.21: Window 1.1 *General Data*, tab *Serviceability Limit State*

Then we enter member No. **1** in the 1.10 *Serviceability Data* window



1.10 Serviceability Data

No.	A Reference to	B Member No.	C Reference Length Manually	D Reference Length L [ft]	E Direction	F Precamber w_c [in]	G Beam Type
1	Member	1	☐	24.00	y	0.00	Beam
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							

Figure 8.22: Window 1.10 *Serviceability Data*

We do not modify the reference length but we restrict the *Direction* to **y**. As a simple span beam, we select the **Beam** in the *Beam Type* list.

Details...

In the dialog box *Details*, tab *Serviceability*, we change one setting: The deformation is to be relative to the **Undeformed system**.

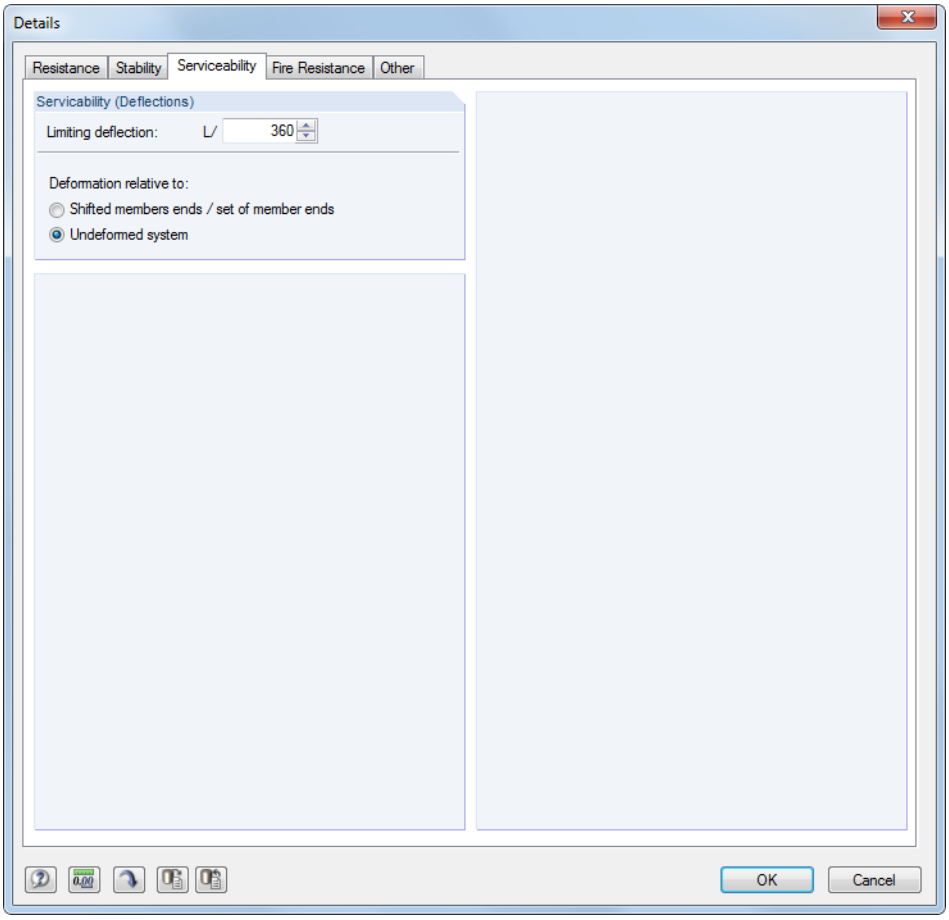


Figure 8.23: Dialog box *Details*, tab *Serviceability*

The limiting deflection is *L/360* according to Table 1604.3 in [6].

For the following equation, the modulus of elasticity of 1800000 psi is applied.

Deflection from moment

$$\Delta_y{}^M = \frac{5}{384} \times \frac{w_{live} \times L^4}{E \times I_x} = \frac{5}{384} \times \frac{87.75 \times 288^4}{1800000 \times 7776} = 0.56\,\text{in}$$

Deflection from shear force (approximate calculation)

$$\Delta_y{}^V = 0.96 \times \frac{E}{G} \times \left(\frac{d}{L}\right)^2 \times \Delta_y{}^M = 0.96 \times \frac{1800000}{112500} \times \left(\frac{24}{288}\right)^2 \times 0.56 = 0.06\,\text{in}$$

Final deflection

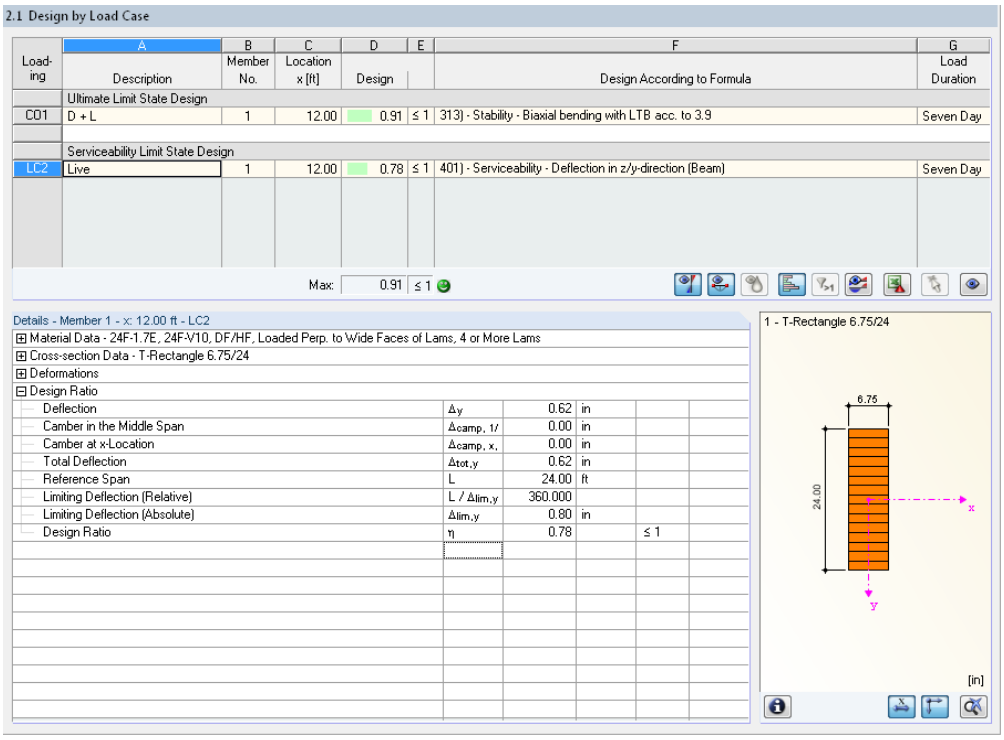
$$\Delta_y = \Delta_y{}^M + \Delta_y{}^V = 0.56 + 0.6 = 0.62\,\text{in}$$

Design

$$\frac{\Delta_y}{\Delta_{lim,y}} = \frac{0.62\,\text{in}}{0.80\,\text{in}} = 0.78 < 1$$

Calculation

The result of this deformation analysis is also displayed in the 2.1 *Design by Load Case* result window under the table entry *Serviceability Limit State Design*.



2.1 Design by Load Case

Loading	A Description	B Member No.	C Location x [ft]	D Design	E	F Design According to Formula	G Load Duration
	Ultimate Limit State Design						
CO1	D + L	1	12.00	0.91	≤ 1	313) - Stability - Biaxial bending with LTB acc. to 3.9	Seven Day
	Serviceability Limit State Design						
LC2	Live	1	12.00	0.78	≤ 1	401) - Serviceability - Deflection in z/y-direction (Beam)	Seven Day
				Max:	0.91	≤ 1	

Details - Member 1 - x: 12.00 ft - LC2

Material Data - 24F-1.7E, 24F-V10, DF/HF, Loaded Perp. to Wide Faces of Lams, 4 or More Lams				
Cross-section Data - T-Rectangle 6.75/24				
Deformations				
Design Ratio				
Deflection	Δ_y	0.62	in	
Camber in the Middle Span	$\Delta_{camp,1/}$	0.00	in	
Camber at x-Location	$\Delta_{camp,x,}$	0.00	in	
Total Deflection	$\Delta_{tot,y}$	0.62	in	
Reference Span	L	24.00	ft	
Limiting Deflection (Relative)	$L / \Delta_{lim,y}$	360.000		
Limiting Deflection (Absolute)	$\Delta_{lim,y}$	0.80	in	
Design Ratio	η	0.78		≤ 1

Figure 8.24: Window 2.1 *Design by Load Case*

8.3 Single Tapered Beam

According to the Design Specification [1], the strength of a tapered beam must be reduced depending on the loading (tensile bending or compressive bending). This usually applies to single tapered beams.

The single tapered beam of the following example is laterally supported over its entire length.

8.3.1 System and Loads

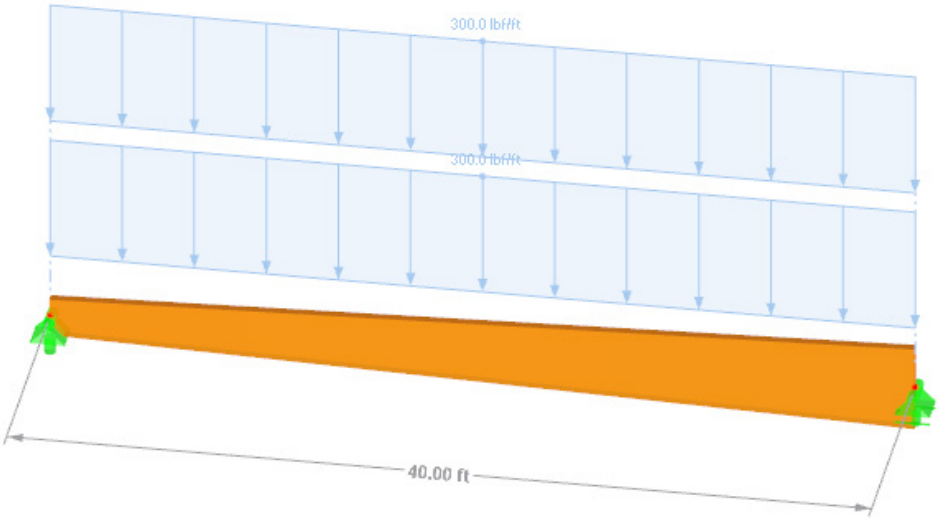


Figure 8.25: System and loads

Model

Material:	Southern Pine 24F-V5
Length:	40 ft
Cross-section 1:	5-1/2 in by 22 in (start)
Cross-section 2:	5-1/2 in by 49-1/2 in (end)
Moisture Condition:	Dry
Temperature Condition:	T ≤ 100°F

Loads

Load Combination:	D + S
LC 1 Dead:	Self-weight and 300 lbf/ft
LC 2 Snow:	300 lbf/ft

8.3.2 Calculation with RFEM

The system as well as the loads in all load cases is modeled in RFEM as a 3D model. We make sure that the automatic self-weight is activated in LC1.

We create the considered load combination with relevant factors from the defined load cases. Then we calculate the model according to the linear static analysis.

RFEM determines the diagrams of internal forces shown in the following figure.

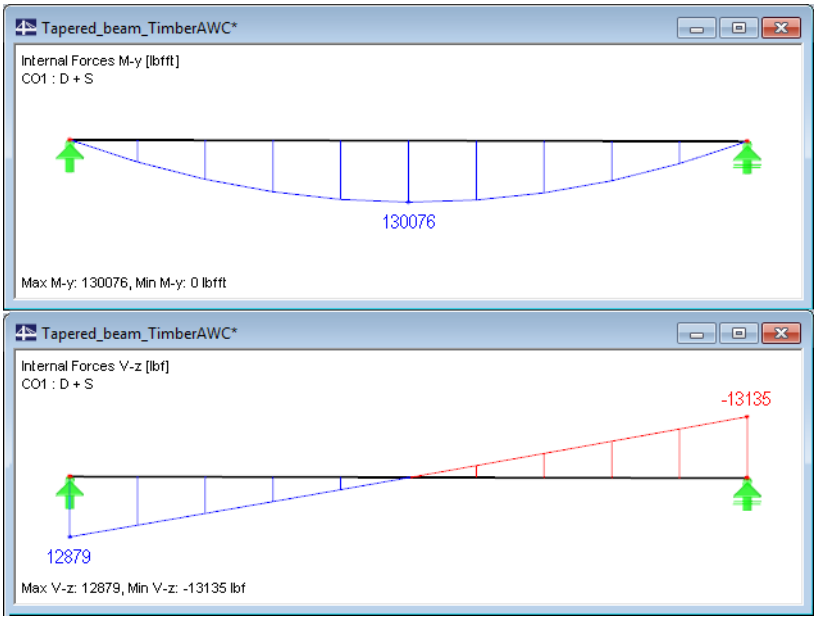


Figure 8.26: Internal forces M_y and V_z

8.3.3 Design with RF-TIMBER AWC

Ultimate Limit State Design

In Window 1.1 *General Data*, we select the result combination **CO1** for the *Ultimate Limit State* design.

We perform the design according to **ASD**.

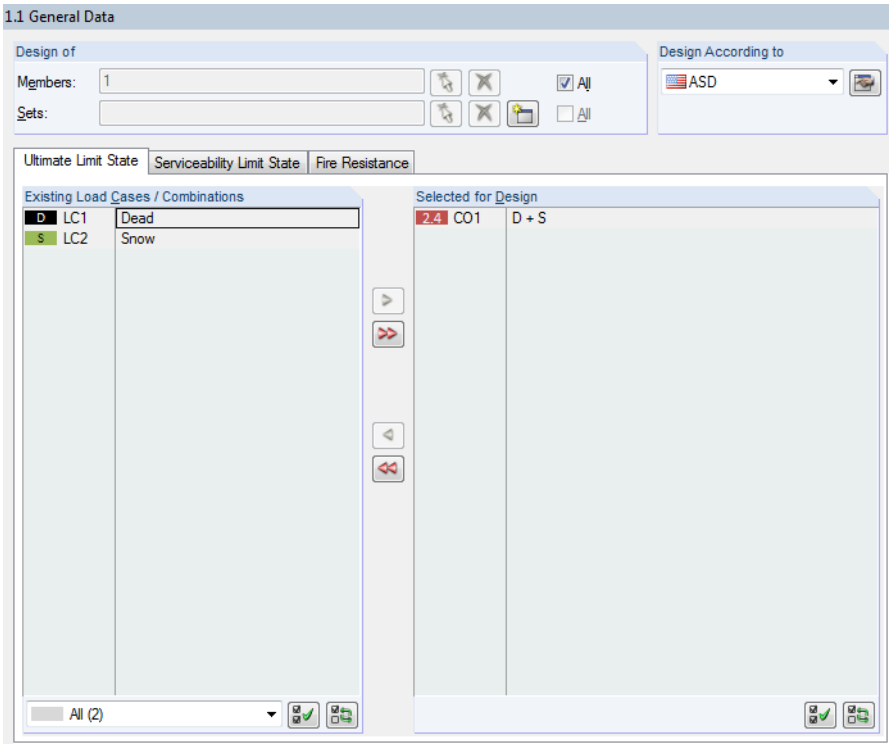


Figure 8.27: Window 1.1 *General Data*

The 1.2 *Materials* window presents the characteristic strengths of the selected material.

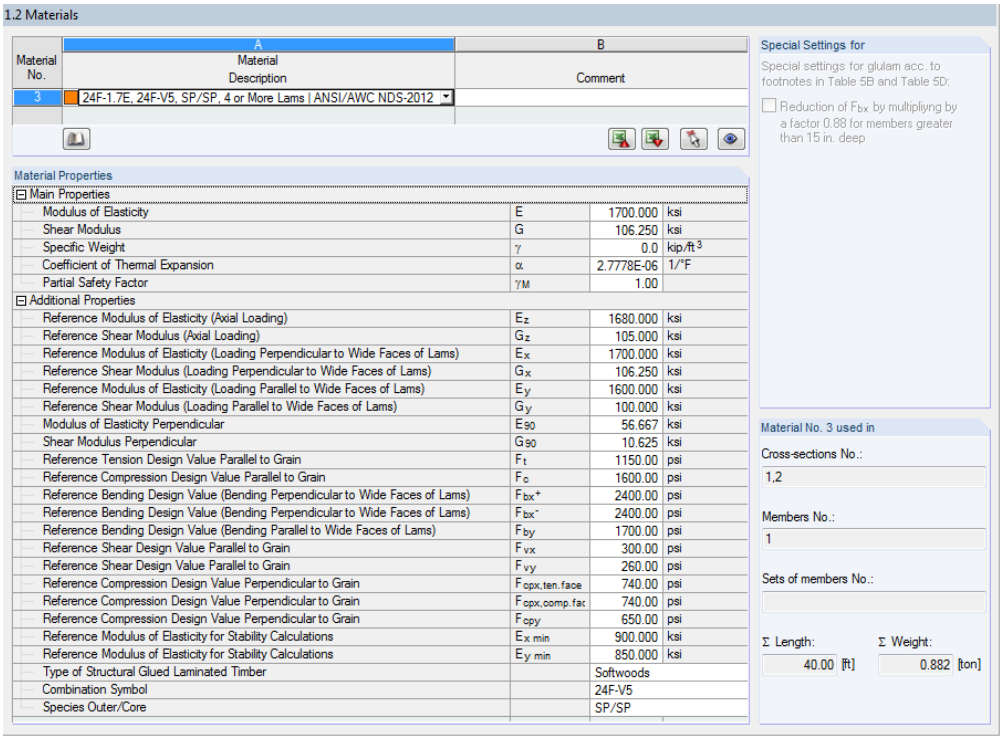


Figure 8.28: Window 1.2 *Materials*

In the 1.3 *Cross-Sections* window, the parameters of the two cross-sections can be checked.

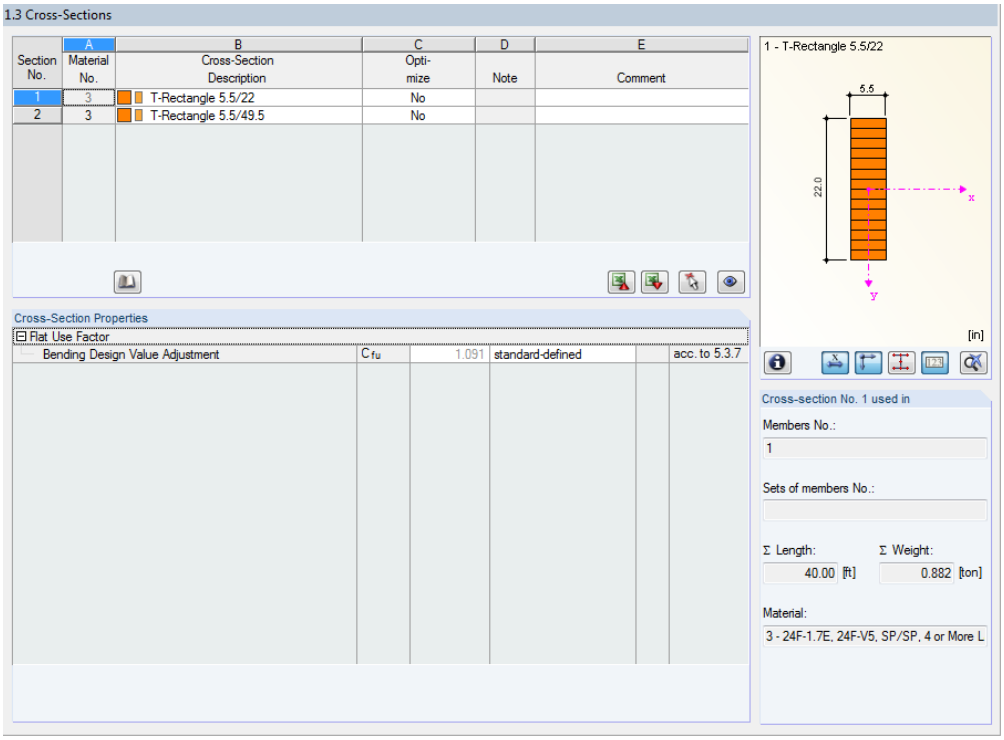


Figure 8.29: Window 1.3 *Cross-Sections*

In Window 1.4 *Load Duration*, we define the load duration. For ASD, the load duration for load combination is assigned according to the shortest load duration included in this combination. The load duration of CO1 is preset as **Two Months**.

As the beam is not loaded by any wind or earthquake load, the load condition for radial stress design according to [1] Table 5.2.8 is set as **Other Types of Loading**.

1.4 Load Duration

Loading	A Description	B Load Type	C Load Duration	D Factor C_D	E Loading Condition (Radial Stress Design)	F Comments
LC1	Dead	Dead	Permanent	0.900	Other Types of Loading	
LC2	Snow	Snow	Two Months	1.150	Other Types of Loading	
CO1	D + S	-	Two Months	1.150	Other Types of Loading	

Figure 8.30: Window 1.4 *Load Duration*

In Window 1.5 *In-Service Condition - Members*, we define the moisture and temperature conditions. The factors C_M and C_T are determined for **dry** service conditions and sustained exposure to elevated temperatures up to 100°F.

1.5 In-Service Conditions - Members

Member No.	A Moisture Service Condition	B Temperature	C Comments
1	Dry	T ≤ 100°F	

Moisture Service Condition

Dry Service Conditions:

Moisture content in service is less than 19% for lumber (less than 16% for glulam)

Wet Service Conditions:

Moisture content in service is 19% or greater for lumber (16% and greater for glulam)

Temperature Effects:

Structural members experience sustained exposure to elevated temperatures up to 100°F

Structural members experience sustained exposure to elevated temperatures between 100°F and 125°F

Structural members experience sustained exposure to elevated temperatures between 125°F and 150°F

Set input for members No.:

All

Figure 8.31: Window 1.5 *In-Service Conditions - Members*

In Window 1.7 *Effective Lengths - Members* we specify the buckling lengths. The beam is laterally supported over its entire length continuously. Therefore, there is no risk of instability. We clear the two check boxes **Buckling Possible** and **Lateral-Torsional Buckling**.

1.7 Effective Lengths - Members

Member No.	A Buckling Possible	B Buckling About Axis x Possible	C Buckling About Axis x K_{ex}	D Buckling About Axis x l_{ex} [ft]	E Buckling About Axis y Possible	F Buckling About Axis y K_{ey}	G Buckling About Axis y l_{ey} [ft]	H Lateral-Torsional Buckling Possible	I Lateral-Torsional Buckling Define l_e	J Lateral-Torsional Buckling l_e [ft]	K Comment
1	☐	☐	1.000	40.00	☐	1.000	40.00	☐	as member length	40.00	

Figure 8.32: Window 1.7 *Effective Lengths - Members*

In Window 1.9 *Additional Design Properties*, the use of further adjustment factors is not required. There is no shear reduction to be applied.

1.9 Additional Design Parameters

Member No.	A Adjustment Factors Description	B Adjustment Factors Definition	C Symbol	D Value [-]	E acc. to	F Comment
1	Shear Reduction Factor	No Shear Reduction	C_{vr}	-	5.3.10	
	Shear Edge-Bonded Factor	Edge-Bonded	-	-	NDS Suppl.	

Set input for members No.: ☑ All

Material Category: Structural Glued Laminated Timber

Figure 8.33: Window 1.9 *Additional Design Parameters*

The tapered member is automatically listed in Window 1.14 *Tapered Members*, including the preset angle of taper which is 3.28°.

1.14 Tapered Members

Member No.	A Cross-Section Member Start	B Member End	C Length L [ft]	D Angle of Taper θ [°]	E Grain Parallel to Edge	F Comment
1	T-Rectangle 5.5/22	T-Rectangle 5.5/49.5	40.00	3.28	+z/+y - axis	

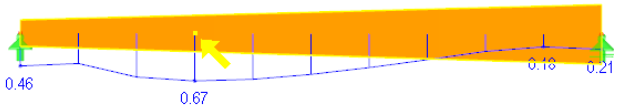
Figure 8.34: Window 1.14 *Tapered Members*

The grain runs parallel to the edge which is located in the direction of the **positive** z/y-axis (this is the bottom side of the member). Thus, the cut face of the beam is in the compressive bending area (it would also be possible to design taper cuts on the tension face, but those cuts are not recommended for structural glued laminated timber beams).

Calculation

We then start the calculation by clicking the [Calculation] button.

After the calculation, the governing design is presented in the 2.1 *Design by Load Case* window.



2.1 Design by Load Case

Loading	A Description	B Member No.	C Location x [ft]	D Design	E	F Design According to Formula	G Load Duration
	Ultimate Limit State Design						
CO1	D + S	1	12.00	0.67	≤ 1	1131) Cross-section resistance - Tapered Member - Strength in bending about y/x-axis acc. to 3.3	Two Months
			Max:	0.67	≤ 1		

Details - Member 1 - x: 12.00 ft - CO1

Material Data - 24F-1.7E, 24F-V5, SP/SP, 4 or More Lams				
Cross-section Data - T-Rectangle 5.5/30.25				
Design Internal Forces				
Adjustment Factors				
Design Ratio				
Bending Moment	M_x	108833	lbfft	
Section Modulus	S_x	838.8	in^3	
Actual Bending Stress	f_{bx}	1556.96	psi	
Partially Adjusted Bending Design Value	F_{bx*}	2760.00	psi	
Cross-Section Breadth	b	5.5	in	
Cross-Section Depth	d	30.3	in	
Length Between Points of Zero Moments	L	40.00	ft	
Constant	x	20		
Volume Factor	C_V	0.921		Eq. (5.3-1)
Angle of Taper	θ	3.28	°	
Parameters for Stress Interaction Factor				
Reference Bending Design Value	F_b	2400.00	psi	Table 5A
Shear Reduction Factor	C_{vr}	0.720		5.3.10
Reference Shear Design Value	F_v	300.00	psi	Table 5A
Reference compression design value perpendicular to grain	$F_{cpx,\ cmp.\ face}$	740.00	psi	Table 5A
Stress Interaction Factor	C_I	0.844		Eq. (5.3-4),ERRATA:2013-11
Adjusted Bending Design Value	$F_{bx',\ ten.\ face}$	2542.77	psi	
Adjusted Bending Design Value	$F_{bx',\ cmp.\ face}$	2328.19	psi	
Design Ratio (Tension Face)	η_1	0.61	≤ 1	3.3.1
Design Ratio (Compression Face)	η_2	0.67	≤ 1	3.3.1
Design Ratio	η	0.67	≤ 1	

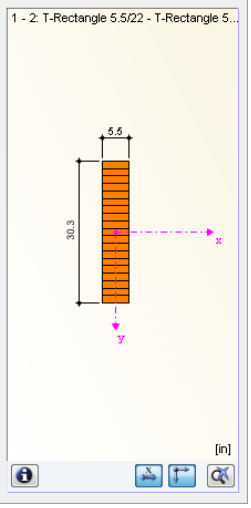


Figure 8.35: Window 2.1 *Design by Load Case*

The beam capacities, which are modified by adjustment factors, are calculated as follows:

Partially Adjusted Bending Design Value

$$F_{bx}* = F_{bx} \times C_M \times C_t \times C_D$$
$$F_{bx}* = 2400 \times 1.0 \times 1.0 \times 1.15$$
$$F_{bx}* = 2760.00 \text{ psi}$$

Adjusted Shear Design Value

$$F_{vx}' = F_{vx} \times C_M \times C_t \times C_D$$
$$F_{vx}' = 300 \times 1.0 \times 1.0 \times 1.15$$
$$F_{vx}' = 345.00 \text{ psi}$$

The stress analysis is performed as follows.

Actual Bending Stress

$$f_{bx} = \frac{M_x}{S_x} = \frac{1305990 \text{ lbf.ft}}{838.81 \text{in}^3} = 1556.96 \text{ psi}$$

Actual Shear Stress Parallel to Grain

$$f_{vx} = \frac{V_x \times Q_x}{I_x \times b} = \frac{12879 \text{ lbf} \times 332.75 \text{ in}^3}{4880.3 \text{ in}^4 \times 5.5 \text{ in}} = 159.66 \text{ psi}$$

The bending design stress must be adjusted also by the lesser of the stress interaction factor, C_I, and volume factor, C_V.

The stress interaction factor depends on the face of taper. For members tapered on the compression side, this factor is calculated as follows.

Stress Interaction Factor

$$C_I = \frac{1}{\sqrt{1 + (\frac{F_b \times \tan\theta}{F_v \times C_{vr}})^2 + (\frac{F_b \times \tan^2\theta}{F_{c\square}})^2}}$$

$$C_I = \frac{1}{\sqrt{1 + (\frac{2400 \times \tan 3.28°}{300 \times 0.72})^2 + (\frac{2400 \times \tan^2 3.28°}{740})^2}}$$

$$C_I = 0.844$$

The volume factor depends on the cross-section dimensions at the verified point on the beam (dimensions and length of bending member between points of zero moment in ft).

Volume Factor

$$C_V = (\frac{21}{L})^{1/x} \times (\frac{12}{d})^{1/x} \times (\frac{5.125}{b})^{1/x}$$
$$C_V = (\frac{21}{40})^{1/20} \times (\frac{12}{30.25})^{1/20} \times (\frac{5.125}{5.50})^{1/20}$$

$$C_V = 0.921$$

With this factor, the total flexural capacity can be calculated as follows.

Adjusted Bending Design Values

$$F_{bx}' = F_{bx}^{*} \times \min(C_I; C_V) = 2760.00 \times \min(0.844; 0.921) = 2329.44 \text{ psi}$$

Bending Design

Design of bending according to [1] Chapter 3.3.1:

Design

$$\frac{f_{bx}}{F_{bx}'} = \frac{1556.96}{2329.44} = 0.67 \leq 1.00$$

Shear Design

Design of shear according to [1] Chapter 3.4.1:

Design 1 (Shear due to shear force V_x)

$$\frac{f_{vx}}{F_{vx}'} = \frac{159.66}{345.00} = 0.46 \leq 1.00$$

8.4 Curved Beam (LRFD Solution)

According to the Design Specification [1], the cross-section resistance design can be also performed for curved sections of bending members. The cross-section must be constant in those parts. In RF-TIMBER AWC, members of that type are not allowed for stability calculations, however.

8.4.1 System and Loads

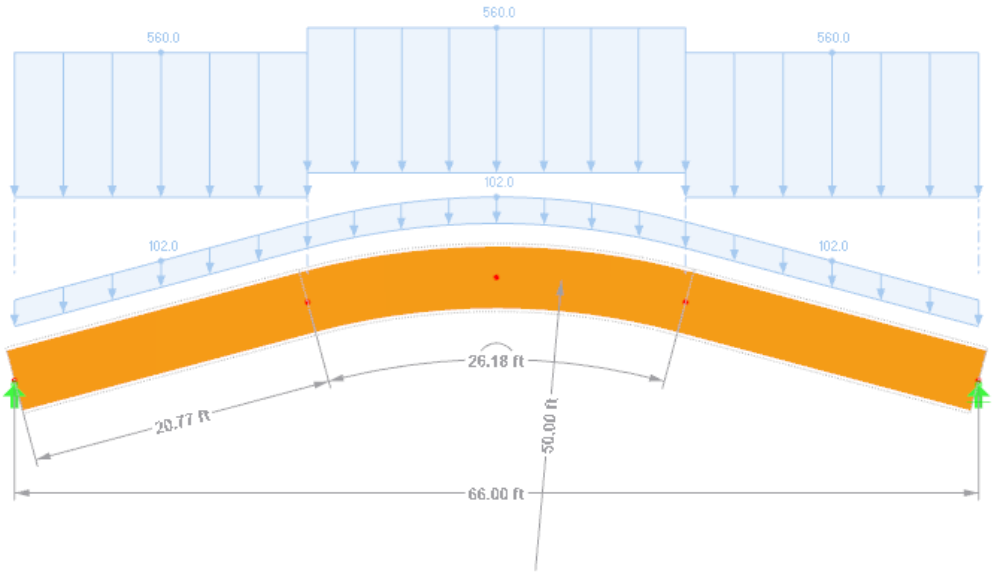


Figure 8.36: System and loads

Model

Material:	Douglas Fir-Larch 16F-V3
Length:	66 ft
Radius of Curvature at Centerline:	50 ft
Cross-section:	8-3/4 in by 51 in
Thickness of Lamination	1-1/2 in
Moisture Condition:	Dry
Temperature Condition:	T ≤ 100°F

Loads

Load Combination:	1.2D + 1.6S
LC 1 Dead:	85 lbf/ft
LC 2 Snow:	350 lbf/ft

8.4.2 Calculation with RFEM

The system as well as the loads in all load cases is modeled in RFEM as a 3D model. We deactivate the automatic consideration of the self-weight when we create LC1.

We create the considered load combination with relevant factors from the defined load cases. Then we calculate the model according to the linear static analysis.

RFEM determines the diagrams of internal forces shown in the following figure.

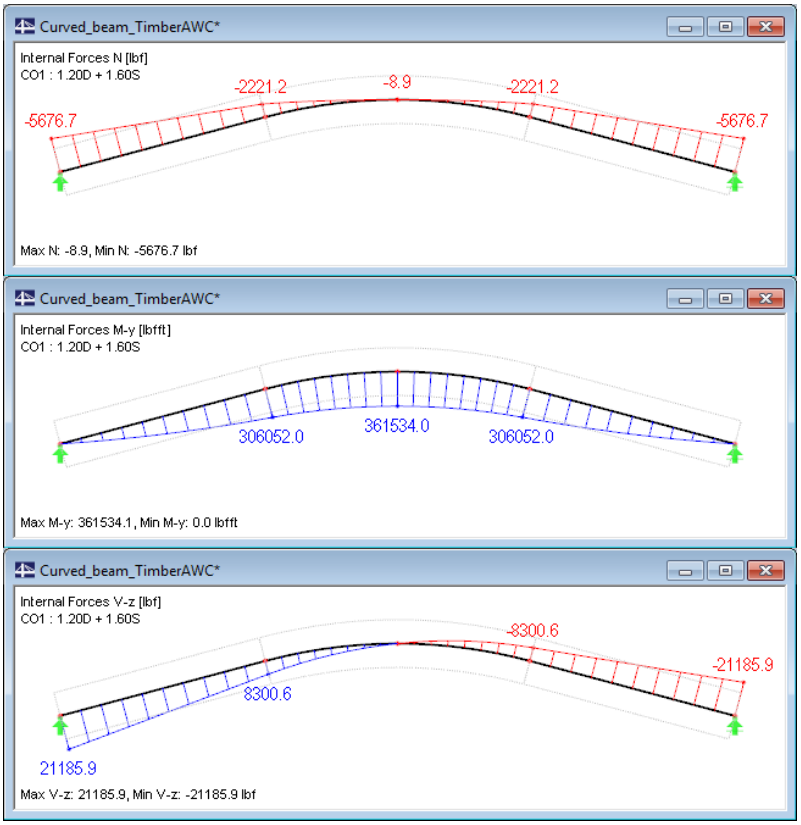


Figure 8.37: Internal forces N, M_y and V_z

8.4.3 Design with RF-TIMBER AWC

Ultimate Limit State Design

In Window 1.1 *General Data*, we select the result combination **CO1** for the *Ultimate Limit State* design. We perform the design according to **LRFD**.

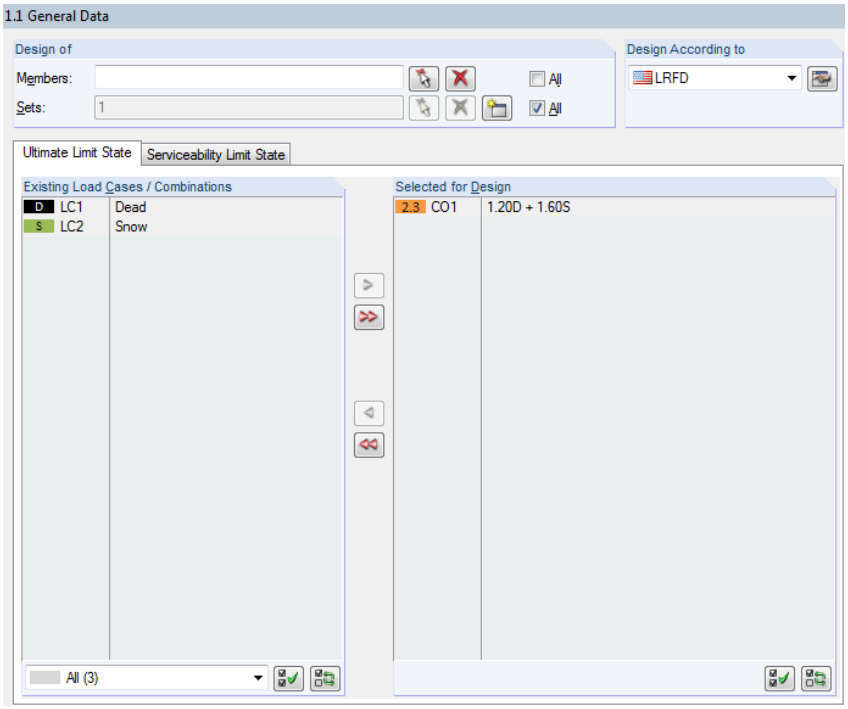
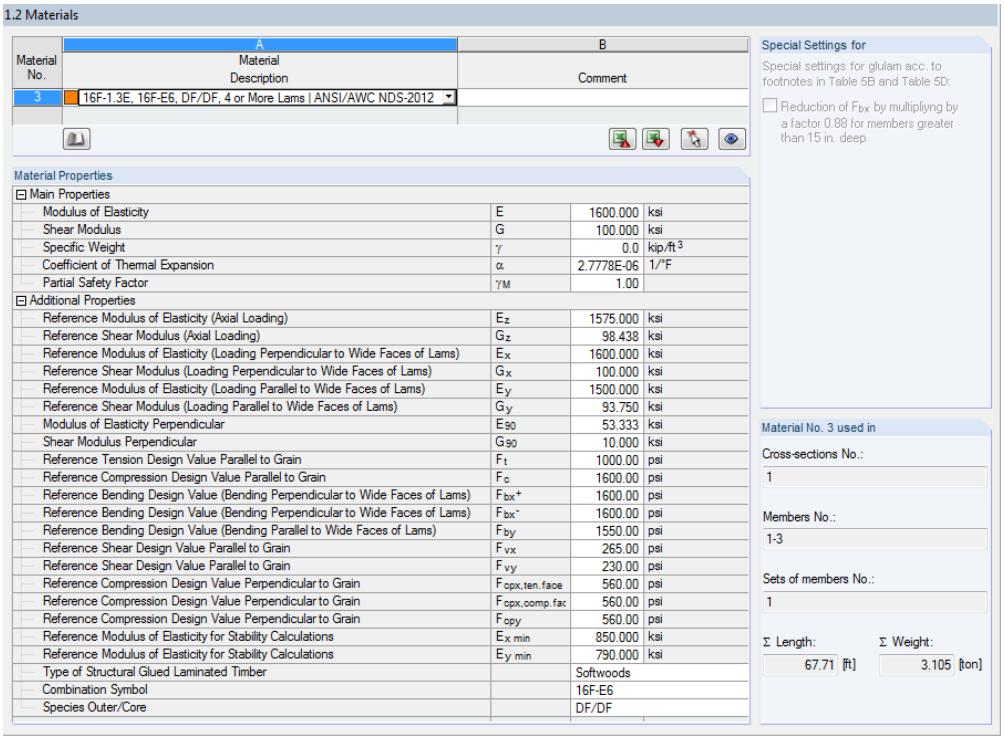


Figure 8.38: Window 1.1 *General Data*

The 1.2 *Materials* window presents the characteristic strengths of the selected material.



1.2 Materials

Material No.	A Material Description	B Comment
3	16F-1.3E, 16F-E6, DF/DF, 4 or More Lams | ANSI/AWC NDS-2012	

Special Settings for

Special settings for glulam acc. to footnotes in Table 5B and Table 5D:

Reduction of F_{bx} by multiplying by a factor 0.88 for members greater than 15 in. deep

Material Properties

Main Properties			
Modulus of Elasticity	E	1600.000	ksi
Shear Modulus	G	100.000	ksi
Specific Weight	γ	0.0	kip/ft³
Coefficient of Thermal Expansion	α	2.7778E-06	1/°F
Partial Safety Factor	γ_M	1.00	
Additional Properties			
Reference Modulus of Elasticity (Axial Loading)	E_z	1575.000	ksi
Reference Shear Modulus (Axial Loading)	G_z	98.438	ksi
Reference Modulus of Elasticity (Loading Perpendicular to Wide Faces of Lams)	E_x	1600.000	ksi
Reference Shear Modulus (Loading Perpendicular to Wide Faces of Lams)	G_x	100.000	ksi
Reference Modulus of Elasticity (Loading Parallel to Wide Faces of Lams)	E_y	1500.000	ksi
Reference Shear Modulus (Loading Parallel to Wide Faces of Lams)	G_y	93.750	ksi
Modulus of Elasticity Perpendicular	E_{90}	53.333	ksi
Shear Modulus Perpendicular	G_{90}	10.000	ksi
Reference Tension Design Value Parallel to Grain	F_t	1000.00	psi
Reference Compression Design Value Parallel to Grain	F_c	1600.00	psi
Reference Bending Design Value (Bending Perpendicular to Wide Faces of Lams)	F_{bx}^+	1600.00	psi
Reference Bending Design Value (Bending Perpendicular to Wide Faces of Lams)	F_{bx}^-	1600.00	psi
Reference Bending Design Value (Bending Parallel to Wide Faces of Lams)	F_{by}	1550.00	psi
Reference Shear Design Value Parallel to Grain	F_{vx}	265.00	psi
Reference Shear Design Value Parallel to Grain	F_{vy}	230.00	psi
Reference Compression Design Value Perpendicular to Grain	$F_{cpx,ten.face}$	560.00	psi
Reference Compression Design Value Perpendicular to Grain	$F_{cpx,comp.fac}$	560.00	psi
Reference Compression Design Value Perpendicular to Grain	F_{cpy}	560.00	psi
Reference Modulus of Elasticity for Stability Calculations	$E_{x\ min}$	850.000	ksi
Reference Modulus of Elasticity for Stability Calculations	$E_{y\ min}$	790.000	ksi
Type of Structural Glued Laminated Timber		Softwoods	
Combination Symbol		16F-E6	
Species Outer/Core		DF/DF	

Material No. 3 used in

Cross-sections No.: 1

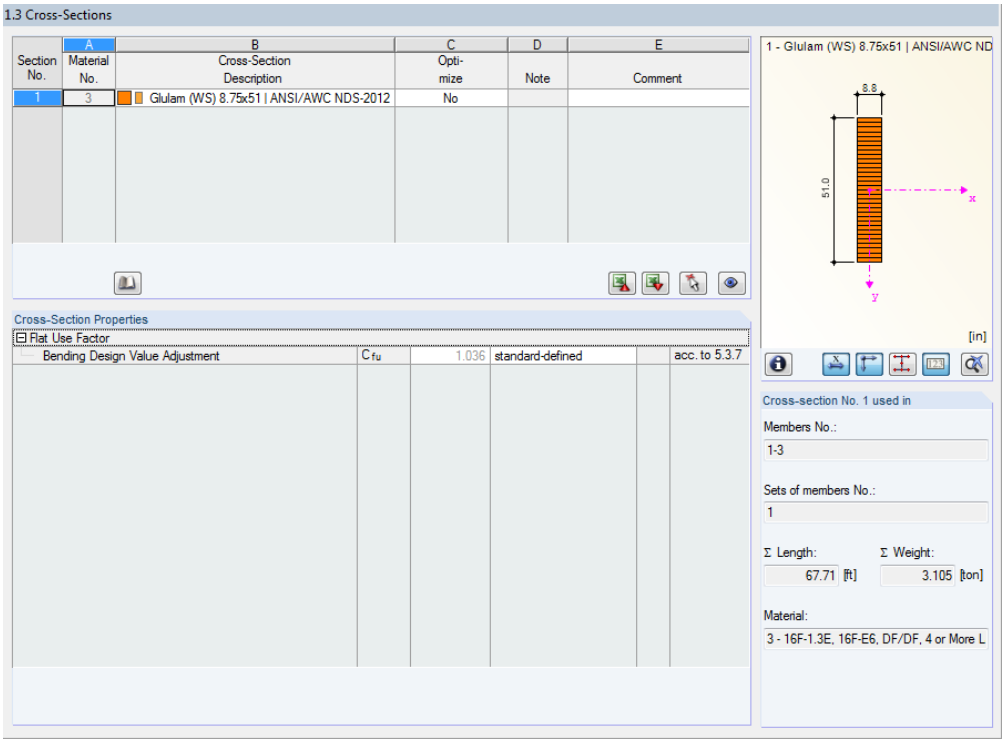
Members No.: 1-3

Sets of members No.: 1

Σ Length: 67.71 [ft] Σ Weight: 3.105 [ton]

Figure 8.39: Window 1.2 *Materials*

In the 1.3 *Cross-Sections* window, the parameters of the glulam section can be checked.



1.3 Cross-Sections

Section No.	A Material No.	B Cross-Section Description	C Optimize	D Note	E Comment
1	3	Glulam (WS) 8.75x51 | ANSI/AWC NDS-2012	No		

Cross-Section Properties

Flat Use Factor					
Bending Design Value Adjustment	C_{fu}	1.036	standard-defined		acc. to 5.3.7

1 - Glulam (WS) 8.75x51 | ANSI/AWC ND

Cross-section No. 1 used in

Members No.: 1-3

Sets of members No.: 1

Σ Length: 67.71 [ft] Σ Weight: 3.105 [ton]

Material: 3 - 16F-1.3E, 16F-E6, DF/DF, 4 or More L

Figure 8.40: Window 1.3 *Cross-Sections*

In Window 1.4 *Load Duration*, we define the load duration. For LRFD, **User-defined settings** are recommended for load combinations because the choice according to the shortest load duration within a combination does not always reflect the appropriate value of the time effect factor λ according to [1] Table N3.

As the beam is not loaded by any wind or earthquake load, the load condition for radial stress design according to Table 5.2.8 in [1] is set as **Other Types of Loading**.

1.4 Load Duration

Load-ing	A Description	B Load Type	C Load Duration	D Factor λ	E Loading Condition (Radial Stress Design)	F Comments
LC1	Dead	Dead	Permanent	0.600	Other Types of Loading	
LC2	Snow	Snow	Two Months	0.800	Other Types of Loading	
CO1	1.20D + 1.60S	-	Two Months	0.800	Other Types of Loading	

Apply time effect factor λ according to: ○ Shortest load duration in a combination ◉ User-defined settings

Figure 8.41: Window 1.4 *Load Duration*

In window 1.6 *In-Service Condition - Set of Members*, we define the moisture and temperature conditions. The factors C_M and C_T are determined as for **dry** service conditions and sustained exposure to elevated temperatures up to 100°F.

1.6 In-Service Conditions - Set of Members

Set No.	A Moisture Service Condition	B Temperature	C Comments
1	Dry	T ≤ 100°F	

Moisture Service Condition

Dry Service Conditions:

Moisture content in service is less than 19% for lumber (less than 16% for glulam)

Wet Service Conditions:

Moisture content in service is 19% or greater for lumber (16% and greater for glulam)

Temperature Effects:

Structural members experience sustained exposure to elevated temperatures up to 100°F

Structural members experience sustained exposure to elevated temperatures between 100°F and 125°F

Structural members experience sustained exposure to elevated temperatures between 125°F and 150°F

☐ Set input for members No.: ☑ All

Figure 8.42: Window 1.6 *In-Service Conditions - Set of Members*

Details...

Since the beam is laterally supported, we deactivate the **stability analysis** in the *Details* dialog box.

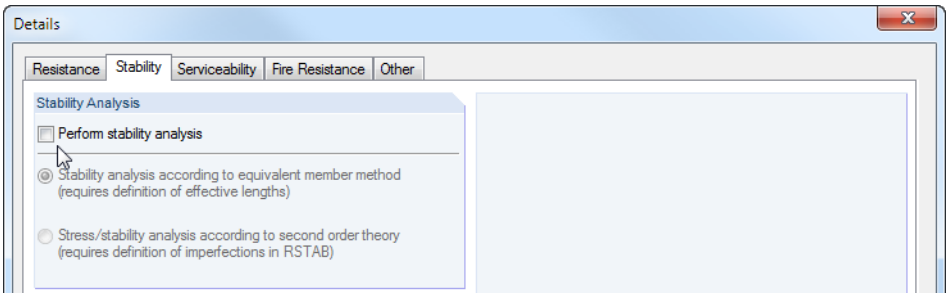
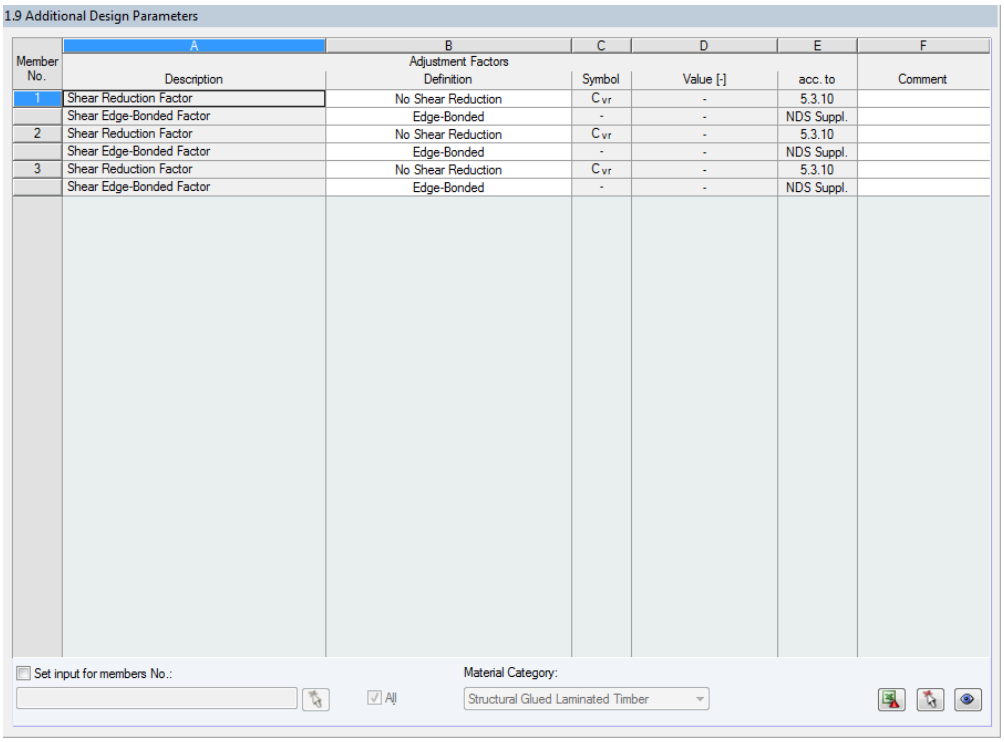


Figure 8.43: Dialog box *Details*, tab Stability

In Window 1.9 *Additional Design Properties*, the use of further adjustment factors is not required. There is no shear reduction to be applied.



1.9 Additional Design Parameters

Member No.	A Description	B Adjustment Factors Definition	C Symbol	D Value [-]	E acc. to	F Comment
1	Shear Reduction Factor	No Shear Reduction	C_{vr}	-	5.3.10	
	Shear Edge-Bonded Factor	Edge-Bonded	-	-	NDS Suppl.	
2	Shear Reduction Factor	No Shear Reduction	C_{vr}	-	5.3.10	
	Shear Edge-Bonded Factor	Edge-Bonded	-	-	NDS Suppl.	
3	Shear Reduction Factor	No Shear Reduction	C_{vr}	-	5.3.10	
	Shear Edge-Bonded Factor	Edge-Bonded	-	-	NDS Suppl.	

Set input for members No.:
All
Material Category:
Structural Glued Laminated Timber

Figure 8.44: Window 1.9 *Additional Design Parameters*

Window 1.11 *Curved Members* controls the input of the curved sections.

1.11 Curved Members

Member No.	A Laminate t [in]	B Minimum Radius of Curvature (Inside Face) R_{MIN} [ft]	C t/R	D	E Radial Stress Design	F Comment
2	1.5	47.88	1 / 383.005	≤ 1 / 125.000	☑	

Figure 8.45: Window 1.11 *Curved Members*

The thickness of the lamellas is set as **1.5 in**. This value is directly reflected in the check of the minimum radius of curvature (inside face of curved member).

We tick the check box in the **Radial Stress Design** column so that RF-TIMBER AWC performs a check of the radial stresses.

Then we start the calculation by clicking the [Calculation] button.

After the calculation, the governing design ratios are shown in the 2.3 *Design by Set of Members* window.

2.3 Design by Set of Members

Set No.	A Member No.	B Location x [ft]	C Load-ing	D Design	E	F Design According to Formula
1	(Member No. 1-3)					
	1	0.00	CO1	0.00	≤ 1	102) Cross-section resistance - Strength in compression parallel to grain acc. to 3.6
	1	0.00	CO1	0.16	≤ 1	111) Cross-section resistance - Strength in shear due to shear force Vz/Vx acc. to 3.4
	1	20.77	CO1	0.48	≤ 1	151) Cross-section resistance - Strength in bending about y/x-axis and compression acc. to 3.9.2
	2	0.00	CO1	0.06	≤ 1	2111) Cross-section resistance - Curved Member - Strength in shear due to shear force Vz/Vx acc. to 3.4
	2	13.09	CO1	0.58	≤ 1	2131) Cross-section resistance - Curved Member - Strength in bending about y/x-axis acc. to 3.3
	2	1.64	CO1	0.51	≤ 1	2151) Cross-section resistance - Curved Member - Strength in bending about y/x-axis and compression acc. to 3.9.2
	2	13.09	CO1	0.94	≤ 1	2201) Cross-section resistance - Curved Member - Radial tension perpendicular to grain acc. to 5.4.1
			Max:	0.94	≤ 1	

Details - Member 2 - x: 13.09 ft - CO1

⊞ Material Data - 16F-1.3E, 16F-E6, DF/DF, 4 or More Lams					
⊞ Cross-section Data - Glulam (WS) 8.75x51 | ANSI/AWC NDS-2012+ADDENDUM:2013-08					
⊞ Design Internal Forces					
⊟ Adjustment Factors					
⊟ Reference Radial Tension Stress					
Reference Radial Tension Stress	F_{rt}	15.00	psi		5.2.8
Wet Service Factor	C_M (F_v)	1.000			5.3.3
Temperature Factor	C_t (F_v)	1.000			5.3.4
Format Conversion Factor	K_F (F_v)	2.880			5.3.14
Resistance Factor	Φ (F_v)	0.750			5.3.15
Time Effect Factor	λ (F_v)	0.800			5.3.16
Adjusted Radial Tension Stress	F_{rt}'	25.92	psi		
⊟ Design Ratio					
Bending Moment	M_x	361534.0	lbfft		
Radius of Curvature at Centerline of Member	R	50.01	ft		
Cross-Section Breadth	b	8.8	in		
Cross-Section Depth	d	51.0	in		
Actual Radial Stress	f_r	24.30	psi		Eq. (5.4-1
Adjusted Radial Tension Design Value	F_{rt}'	25.92	psi		
Design Ratio	η	0.94		≤ 1	5.4.1.3

1 - Glulam (WS) 8.75x51 | ANSI/AWC ND..

Figure 8.46: Window 2.3 *Design by Set on Members*

The capacities of the curved member, which are modified by adjustment factors, are calculated as follows:

Curvature Factor

$$C_c = 1 - 2000 \times (t/R)^2$$
$$C_c = 1 - 2000 \times (1.5/574.56)^2$$
$$C_c = 0.986373\,\text{psi}$$

Partially Adjusted Bending Design Value

$$F_{bx}{}^* = \lambda \times K_F \times \Phi \times F_{bx} \times C_c \times C_M \times C_t$$
$$F_{bx}{}^* = 0.8 \times 2.54 \times 0.85 \times 1600 \times 0.986373 \times 1.0 \times 1.0$$
$$F_{bx}{}^* = 2725.86\,\text{psi}$$

Adjusted Shear Design Values

$$F_{vx}' = F_{vx} \times C_M \times C_t \times K_F \times \Phi \times \lambda$$
$$F_{vx}' = 265 \times 1.0 \times 1.0 \times 2.88 \times 0.75 \times 0.8$$
$$F_{vx}' = 457.92\,\text{psi}$$

Adjusted Radial Tension Stress

$$F_{rt}' = F_{rt} \times C_M \times C_t \times \Phi \times \lambda$$
$$F_{rt}' = 15 \times 1.0 \times 1.0 \times 2.88 \times 0.75 \times 0.8$$
$$F_{rt}' = 25.92\,\text{psi}$$

The stress analysis is performed as follows.

Actual Bending Stresses

$$f_{bx} = \frac{M_x}{S_x} = \frac{361534\,\text{lbf.ft}}{3793.1\text{in}^3} = 1143.76\,\text{psi}$$

Actual Shear Stress Parallel to Grain

$$f_{vx} = \frac{V_x \times Q_x}{I_x \times b} = \frac{21186\text{lbf} \times 2844.84\,\text{in}^3}{96724.70\text{in}^4 \times 8.75\,\text{in}} = 71.21\text{psi}$$

Actual Radial Stress

$$f_r = \frac{3 \times M_x}{2 \times R \times b \times d} = \frac{3 \times 361534\,\text{lbf.ft}}{2 \times 50.0 \times 8.75 \times 51.0} = 24.30\,\text{psi}$$

The bending design stress must be adjusted also by the volume factor, C_v. This factor depends on the cross-section dimensions at the verified point on the beam (dimensions and length of bending member between points of zero moment in ft.).

Volume Factor

$$C_V = \left(\frac{21}{L}\right)^{1/x} \times \left(\frac{12}{d}\right)^{1/x} \times \left(\frac{5.125}{b}\right)^{1/x}$$
$$C_V = \left(\frac{21}{67.72}\right)^{1/10} \times \left(\frac{12}{51.0}\right)^{1/10} \times \left(\frac{5.125}{8.75}\right)^{1/10}$$

$$C_V = 0.7296$$

With this factor, the total flexural capacity can be calculated as follows.

Adjusted Bending Design Values

$$F_{bx}' = F_{bx}^{*} \times C_V = 2725.86 \times 0.7296 = 1988.79 \text{ psi}$$

Bending Design

Design of bending according to [1] Chapter 3.3.1:

Design

$$\frac{f_{bx}}{F_{bx}'} = \frac{1143.76}{1988.79} = 0.58 \leq 1.00$$

Shear Design

Design of shear according to [1] Chapter 3.4.1:

Design

$$\frac{f_{vx}}{F_{vx}'} = \frac{71.21}{457.92} = 0.16 \leq 1.00$$

Radial Tension Design

Design of radial stress according to [1] Chapter 5.4.1.3:

Design

$$\frac{f_r}{F_{rt}'} = \frac{24.30}{25.92} = 0.94 \leq 1.00$$

A Literature

[1] ANSI/AWC NDS-2012: National Design Specification for Wood Construction; August 15, 2011

[2] ANSI/AWC NDS-2012: Supplement National Design Specification Design Values for Wood; November, 2011

[3] ANSI/AF&PA NDS-2005: National Design Specification for Wood Construction with Commentary and Supplement: Design Values for Wood Construction; January 6, 2005

[4] Structural Wood Design Solved Example Problems – ASD/LRFD; Dan L. Wheat, Ph.D., P.E., Steven M. Cramer, Ph.D., P.E.; February, 2007

[5] Structural Wood Design – A Practice-Oriented Approach Using the ASD Method; Abi Aghayere, Jason Vigil; 2007

[6] IBC 2012: 2012 International Building Code, May 2011

B Index

A

Additional design parameters 31
Adjustment factor 31
Angle of taper 36
ASD 9
Axis 28
Axis system 19

B

Background graphic 55
Beam type 33
Buckling 27
Buckling length 26, 28, 73
Buckling length coefficient 28
Button 54

C

Cantilever 33
Charring rate 14
Clipboard 67
Color spectrum 58
Colored design 58
Comment 9
Condition treatment factor 31
Connection 38
Control panel 58
Cross-section 18, 36, 64
Cross-section design 46
Cross-section info 21
Cross-section library 19
Cross-section optimization 64
Curvature 32
Curved members 29, 32, 97

D

Decimal places 16, 66
Deformation analysis 33, 88
Design 9, 21, 44, 45, 46
Design case 55, 62, 63
Design method 12
Design ratio 45
Design stress to member strength factor 14
Detail settings 38
Display navigator 56, 58

E

Effective length 26, 30, 67
Equivalent member 30
Equivalent member length 26, 28
Equivalent member method 40
Evaluation of results 54
Excel 68
Exit RF-TIMBER AWC 8
Export 67
Export cross-section 65
Export effective length 67
Export material 67
Exposure to fire 34

F

Filter 58
Filtering members 59
Fire classification 41
Fire resistance 12
Fire resistance design 34, 35, 41, 54
Flat use factor 19
Flexural buckling 27

G

General data 8
Grain 36
Graphic 55
Graphic printout 60
Graphical representation 56

H

Hidden result diagram 58

I

Imperfections 40
In service conditions 24, 25
Incising factor 31
Installation 6
Internal forces 49, 65

L

Laminate 32
Lateral-torsional buckling 28, 40
Lateral-torsional buckling analysis 40
Length 52
Length for lateral-torsional buckling 28
Limit tension stress 38

Limit values ... 11
Load case ... 10, 11, 49
Load combination ... 10
Load duration ... 23, 46
Load duration factor ... 14, 23
Load sharing factor ... 31
Load type ... 23
Loading condition ... 24
Location x ... 45
LRFD ... 9

M

Material ... 16, 67
Material description ... 16
Material library ... 17
Material properties ... 16
Member list ... 33
Member slendernesses ... 51
Members ... 9

N

Navigator ... 8
Negative bending ... 39

O

OpenOffice ... 68
Optimization ... 21, 42, 64, 65

P

Panel ... 7, 56, 58
Parametrized cross-section ... 19, 64
Part ... 52
Parts list ... 52, 53
Positive bending ... 39
Precamber ... 33
Print ... 22, 60
Printout report ... 60, 61

R

Radial stress design ... 32
Reference design value ... 18
Reference length ... 11
Relation scales ... 54
Remark ... 21
Rendering ... 58
Repetitive factor ... 31
Resistance ... 38
Result combination ... 10
Result diagram ... 57, 60
Results values ... 55
Results window ... 44
RFEM graphic ... 60
RFEM work window ... 55
RF-STABILITY ... 27

S

Second-order analysis ... 40
Selecting windows ... 8
Serviceability ... 33
Serviceability limit state ... 11, 40, 54, 86
Set of members ... 9, 25, 30, 33, 35, 47, 50, 53
Shear reduction factor ... 31
Size factor ... 19
Slenderness ... 42, 51
Stability analysis ... 39, 46
Standard ... 15
Standardized cross-section ... 19
Start calculation ... 43
Start RF-TIMBER AWC ... 6
Stress point ... 22
Sum ... 53
Surface area ... 52

T

Tapered member ... 22, 36, 46, 89
Temperature factor ... 14, 24
Time effect factor ... 14, 23
Torsion design ... 39

U

Ultimate limit state ... 10, 54, 80
Units ... 16, 66
User profile ... 66

V

View mode ... 54, 55
Visibilities ... 58
Volume ... 53

W

Weight ... 53
Wet service factor ... 14, 24
Windows ... 8

X

x-location ... 45, 49