Program

RSBUCK

For use with Windows 95/98/ME/NT 4.0/2000

Effectic Buckling Lengths, Buckling Loads, Critical Load Factors and Buckling Shapes according Eigenvalue Analysis

User Manual

Version: Mai 2001

Am Zellweg 2 • 93464 Tiefenbach • Germany

Telephone: +49 - 96 73 – 92 03 23
Telefax: +49 - 96 73 - 17 70
eMail: info@dlubal.com
Internet: http://www.dlubal.com

1. Introduction....1
1.1 ABOUT RSBUCK FOR WINDOWS....1
1.2 THE RSBUCK TEAM....1

2. Installing RSBUCK....2
2.1 SYSTEM REQUIREMENTS....2
2.2 INSTALLATION PROCESS....2

3. Working with RSBUCK....3
3.1 STARTING RSBUCK....3
3.2 MASKS....3
3.3 INPUT MASKS....3
3.3.1 Mask1.1 General Data....4
3.3.2 Mask 1.2 Normal Forces....5
3.4 RESULT MASKS....6
3.4.1 Mask 2.1 Buckling Lengths and Loads....6
3.4.2 Mask 2.2 Buckling Shapes....7
3.4.3 Mask 2.3 Critical Load Factors....8
3.5 MENUS....9
3.5.1 File....9
3.5.2 Help....10

4. Results....11
4.1 SCREEN VIEWS....11
4.2 PRINTING....12

5. Examples....15
5.1 EULER´S CASE I....15
5.2 FRAME WITH K-BRACING....16
5.3 FRAME WITH HINGED COLUMNS....18
5.4 FRAME WITH A HINGED COLUMN....19
5.5 FRAMED STRUCTURE....19

Appendix: Literature Reference....21

1. Introduction

1.1 About RSBUCK for Windows

Whether you are a first time RSBUCK user or someone using a previous version, the practical oriented development has made it possible for anyone to start the program and find their way around. Much of RSBUCK´s user friendliness comes from the cooperative work with customers and business partners. Their valuable tips contributed to improvements in RSBUCK 4.xx and ultimately in this version of RSBUCK for Windows.

RSBUCK for Windows is fully integrated into RSTAB 5 for Windows. Eigenvalue analysis results can be integrated into the RSTAB printout report. Therefore, the results of all calculations are presented in one concise, complete report.

While working with RSBUCK, the [F1] key can be used to open the online help system.

We wish you much success with RSTAB and RSBUCK.

ING.-SOFTWARE DLUBAL GMBH

1.2 The RSBUCK Team

The following people contributed to the development of RSBUCK for Windows:

- **Program Coordinators:**
  Dipl.-Ing. Georg Dlubal
  Dipl.-Ing. Peter Achter
  Ing. Pavel Bartoš
- **Programmers:**
  Mirza Had•i•
  Dr.-Ing. Jaroslav Lain
- **Program Testing:**
  Dipl.-Ing. Georg Dlubal
  Dipl.-Ing. Peter Achter
  Dipl.-Ing. (FH) Walter Rustler
- **Manual and Help System:**
  Dipl.-Ing. Peter Achter
  Dipl.-Ing. (FH) Andreas Wopperer
- **English Translation:**
  Jana Rustler
  Dipl.-Ing. (FH) Walter Rustler

2. Installing RSBUCK

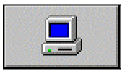
2.1 System Requirements

To use RSBUCK, we recommend the following minimum system requirements:

- Windows 95 / 98 / NT 4.0 or Windows 2000 Operating System
- 200 MHz Processor
- 32 MB Memory
- CD ROM and 3.5” disk drive for installation
- 2 GB total hard disk capacity with 150 MB reserved for installation
- 4 MB Graphic’s card and monitor with a resolution of 1024 x 768 pixels

With the exception of the operating system, no product recommendations are made. RSBUCK and RSTAB basically run on all systems that fulfill the system requirements. Your computer does not need to have “Intel Inside”, and it is also unnecessary to have an expensive 3D graphic’s card. Because RSBUCK and RSTAB are generally used for extensive calculations, the phrase “more is better” holds true.

2.2 Installation Process

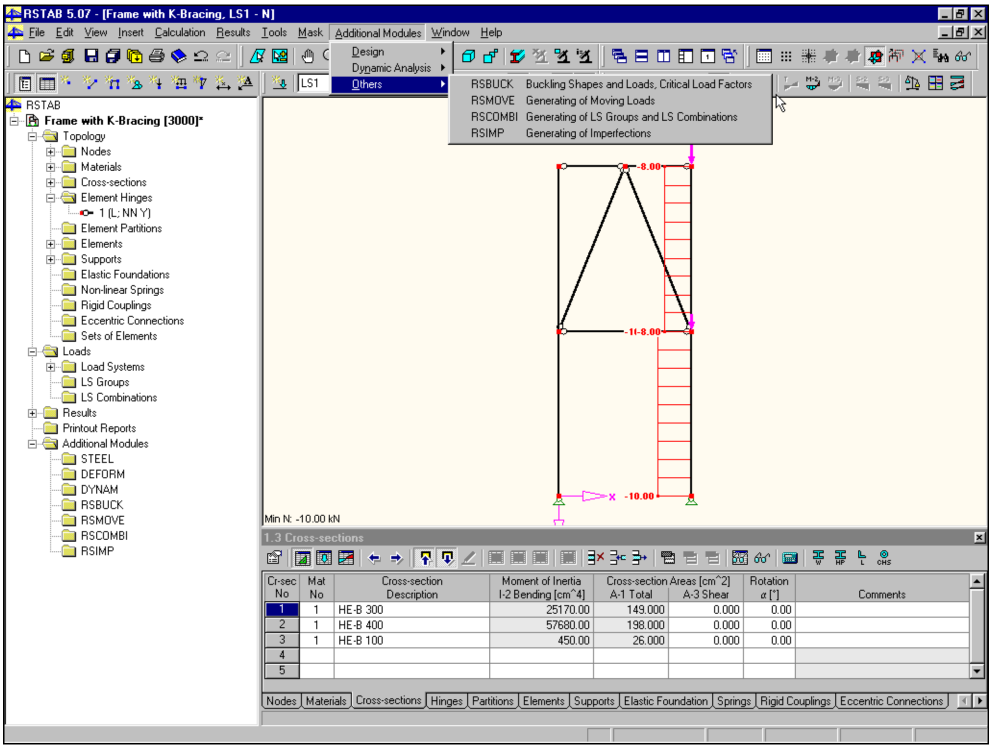


Licensed RSBUCK users should follow the installation instructions in the RSTAB manual. RSBUCK will be automatically installed. If there is an authorization fail message when starting the RSBUCK module from RSTAB, the program will run as a limited but functional demo version.

3. Working with RSBUCK

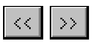
3.1 Starting RSBUCK

RSBUCK can either be started from the *Additional Modules→RSBUCK* menu or by selecting it from [Additional Modules] in the *Position* or *Project Navigator* on the left side of the screen.



Starting RSBUCK with the Menu or the Navigator

3.2 Masks



Input to define Eigenvalues and the output for numerical results can be done with masks. RSBUCK has its own Navigator with all available masks shown to the left. Skim backward or forward through the list with the [F2] and [F3] keys or with the [<<] and [>>] buttons at the bottom of each mask. Click on the [Graphic] button to view results of the buckling shape graphically. (You will find other information about viewing results in Chapter 3.4.)

[OK] saves the input and results before leaving RSBUCK. [Cancel] ends RSBUCK without saving any work done. The [Help] button or the [F1] key will activate the online help system.

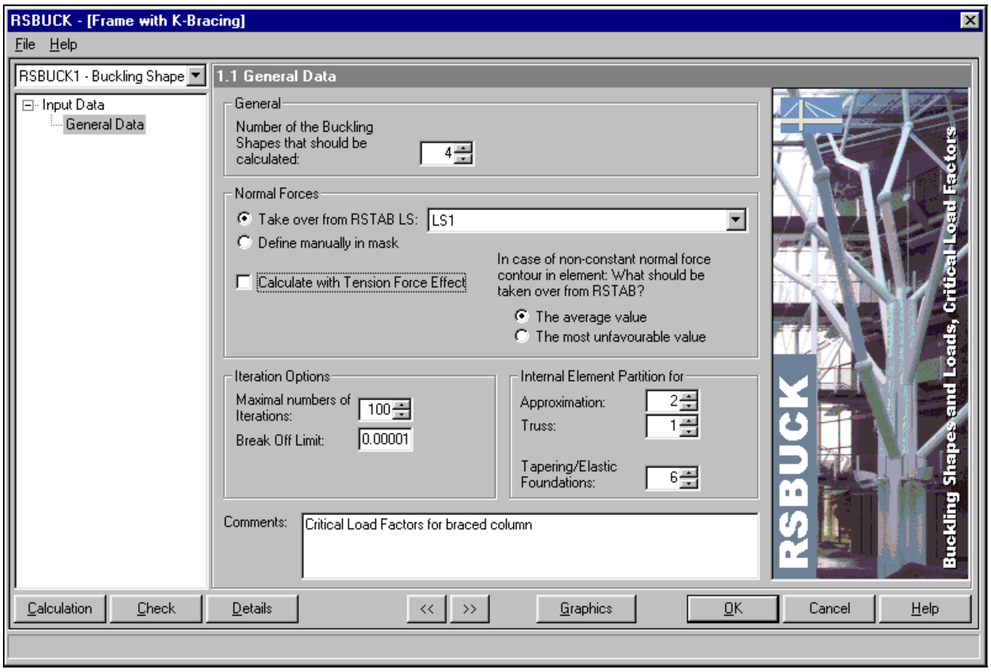
The title bar at the top has *File* and *Help* menus. Refer to Chapter 3.5 for the explanation of their functions.

3.3 Input Masks

Input masks are used to enter parameters for determining effective lengths, buckling loads, buckling shapes and critical load factors.

3.3.1 Mask1.1 General Data

After starting RSBUCK, the *1.1 General Data* mask opens.



Mask 1.1 General Data

Select an existing RSBUCK case with the help of the list box. You can write *Comments* in a field for each RSBUCK case.

Number of Buckling Shapes that should be calculated: RSBUCK determines the most unfavorable buckling shapes of a structure. In theory it is not possible to rule out lower Eigenvalues from the analysis and determine higher Eigenvalues at the same time. With RSBUCK, the 200 lowest Eigenvalues of a system can be determined.

Normal Forces: It is not necessary to *Import results from RSTAB LS* to determine the buckling shapes. The normal forces having an effect on the structure can be *Defined manually in mask*. When you check this option, the *1.2 Normal Forces* mask opens and the normal forces having an effect on elements can be user-defined.

Calculate with Tension Force Effect: Normal tensile forces having an effect in the structure are taken into consideration for determining the Eigenvalues. If this option is not activated the tensile forces will be set to zero internally.

To calculate the critical load factors only the normal (axial) forces are needed. The normal forces may be not constant along an element and the question is posed, *In case of non-constant normal force contour in element. What should be taken over from RSTAB?*

The average value: Select this option so that RSBUCK reads in the average normal forces on the individual elements. The value on the element beginning is added to the value on the element ending and divided by two to find the average used by the program.

The most unfavorable value: When this option is selected, RSBUCK reads in the most unfavorable (= most negative) normal force and considers this as a constant force running over the element.

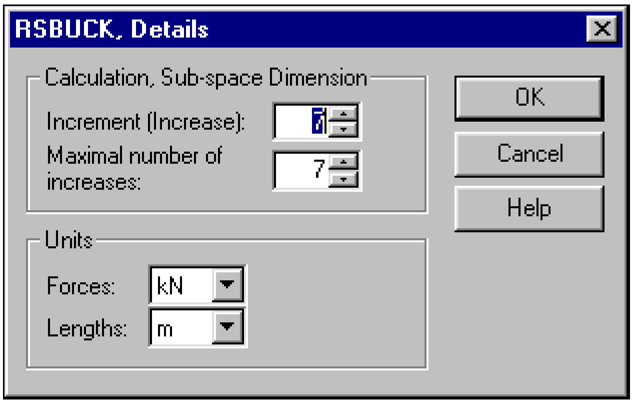
Iteration Options: Buckling shape determination is done with the help of the system's Eigenvalue. An iterative equation solution is used. In general, two break off limits are assumed for iterative calculation procedures so that an exact solution can be approximated but never reached. The *Maximal Number of Iterations* indicates after which iteration step the computing should end. The program cannot determine whether the iteration converges and ends with a better result as more iterations are performed. In some cases the iteration might be divergent and no useful result might be found. The *Break Off Limit* is applied for converged problems when an approximate solution can be regarded as an exact solution and the iteration can be ended.

Internal Element Partition for: To reach a more approximate solution, it may be necessary to define more element partitions. That way the precision of the element model is increased. This is particularly recommended for tapered or elastic bedded elements. RSBUCK will carry out an element partition when whole numbers greater than 1 are entered. There are three different partitions that can be set individually for *Approximation*, *Truss* and *Tapering/Elastic Foundation*. A higher partitioning will increase the possible Eigenvalues and vice versa.

Example: For a single-span beam a maximum of 6 lowest Eigenvalues can be calculated with a partition of 1. After entering 2 in *Approximation* Method the 12 lowest Eigenvalues can be calculated. To reach the same result in RSTAB, the single-span beam would need to be divided by a node in-between.

We recommend to set the partition for *Truss* to "1" if the local Eigenvalues of truss elements should not be considered. Not so many Eigenvalues may have to be calculated before you find the global shapes of buckling.

Comments: Particular notes can be entered here.



RSBUCK, Details

Calculation, Subspace Dimension: If the program doesn't find positive Eigenvalues when considering the previously entered number of iterations, keep increasing the subspace iteration through the *Increment (Increase)* field. The larger the subspace, the better the convergence. Because the calculation method converges against the minimum absolute value of the Eigenvalue, negative Eigenvalues can also result. To find the lowest positive Eigenvalue, it makes sense to increase the subspace. Try to change the two values at *Increment (Increase)* and *Maximal number of increases* if you have problems finding positive Eigenvalues.

The ***Units*** for *Forces* and *Length* are selected with the drop down list box.

3.3.2 Mask 1.2 Normal Forces

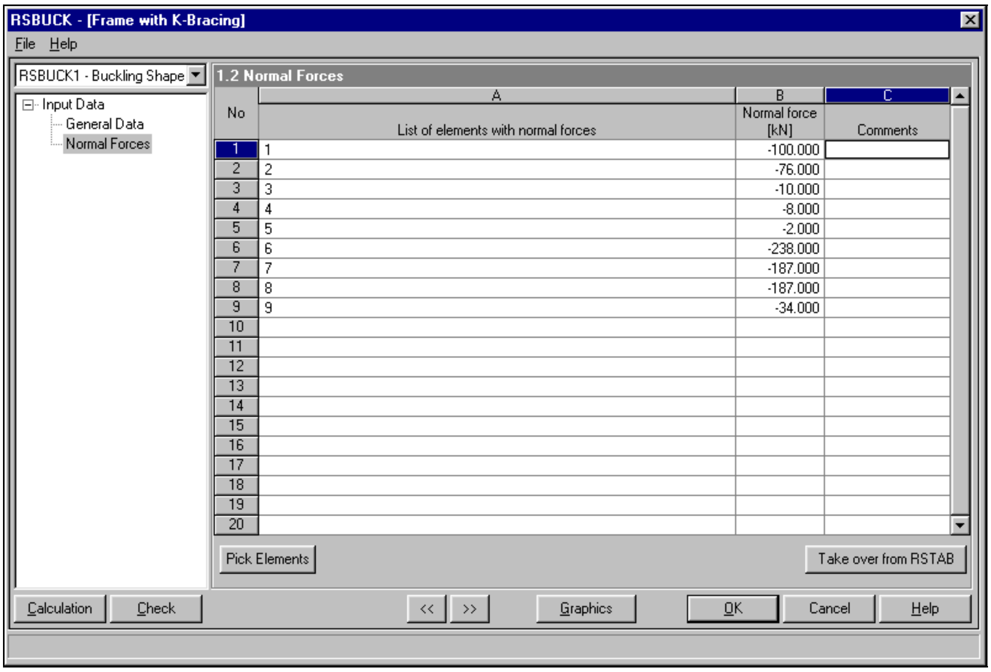
The *1.2 Normal Forces* mask opens when the *Define manually in mask* option is checked in the *1.1 General Data* mask.

List of Elements with Normal Forces
Enter the element numbers to apply normal forces to in column A. Use a hyphen between consecutive elements in a line and a comma between single elements in a line. Click on the [Pick Elements] button to graphically select elements for this input mask.

Normal Force
Enter the value of the Normal Force for the elements in the list. Use the [Import from RSTAB LS] button to import the Normal Forces from an RSTAB load system.

Comments

For extra information *Comments* can be entered.



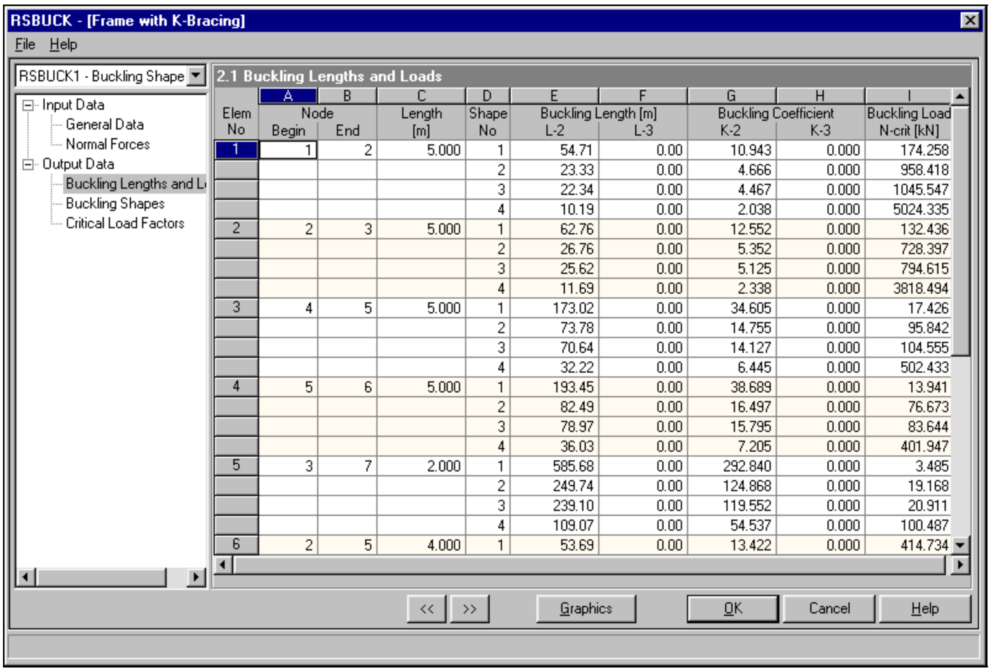
Mask 1.2 Normal Forces

3.4 Result Masks

The result masks show complete and detailed results from the analysis.

3.4.1 Mask 2.1 Buckling Lengths and Loads

After the successful calculation, RSBUCK shows the first results in the *2.1 Buckling Lengths and Loads* mask.



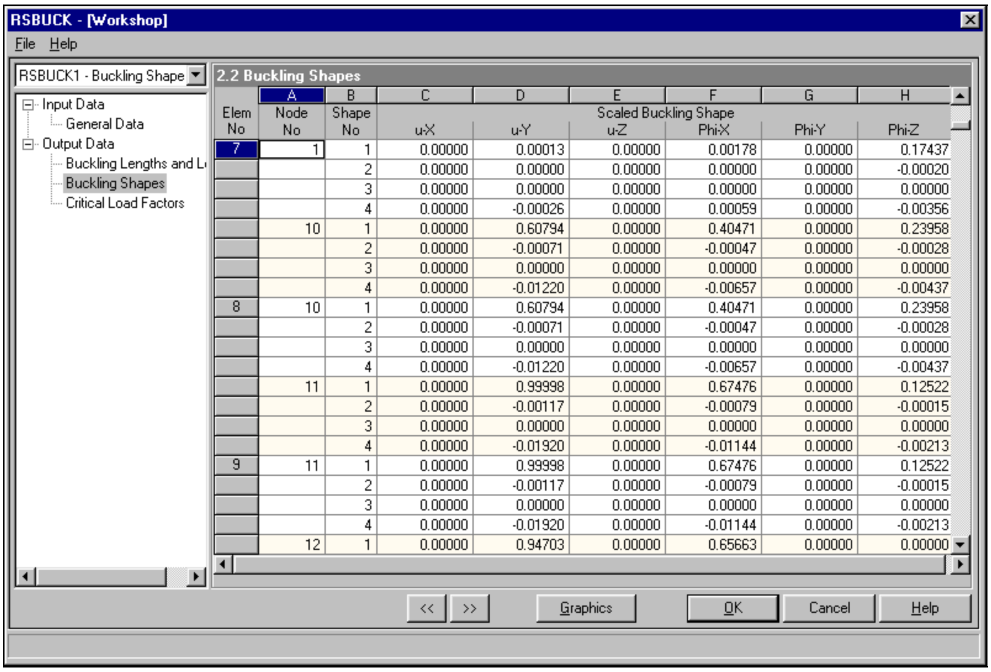
Mask 2.1 Buckling Lengths and Loads

The results will be sorted by elements:

Columns A,B:	Beginning and Ending nodes of the respective elements.
Column C:	Element Length
Column D:	Buckling Shape Number
Columns E, F:	Buckling Length L-2 about the directions of local axes 2 and 3.
Columns G, H:	Buckling Coefficients β about the directions of local axes 2 and 3.
Column I:	Buckling Load N-critical

3.4.2 Mask 2.2 Buckling Shapes

The node displacement and rotation results for each buckling shape are shown in this mask. The deformation is standardized on 1. Use the [Graphics] button to view the buckling shapes graphically.



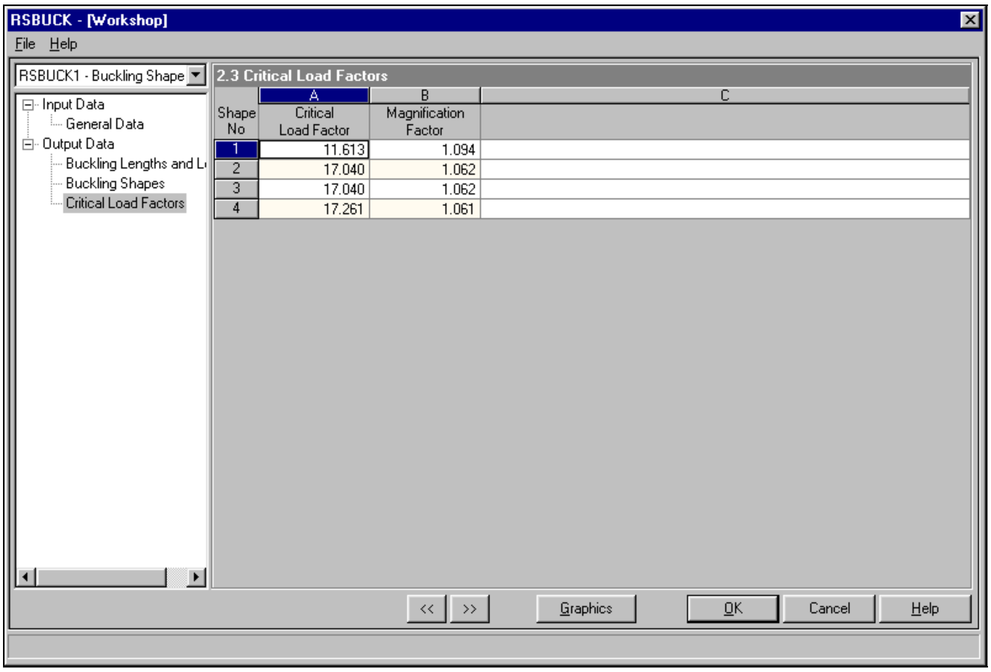
	A	B	C	D	E	F	G	H
Elem No	Node No	Shape No	Scaled Buckling Shape u-X	u-Y	u-Z	Phi-X	Phi-Y	Phi-Z
7	1	1	0.00000	0.00013	0.00000	0.00178	0.00000	0.17437
		2	0.00000	0.00000	0.00000	0.00000	0.00000	-0.00020
		3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
		4	0.00000	-0.00026	0.00000	0.00059	0.00000	-0.00356
	10	1	0.00000	0.60794	0.00000	0.40471	0.00000	0.23958
		2	0.00000	-0.00071	0.00000	-0.00047	0.00000	-0.00028
		3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
		4	0.00000	-0.01220	0.00000	-0.00657	0.00000	-0.00437
8	10	1	0.00000	0.60794	0.00000	0.40471	0.00000	0.23958
		2	0.00000	-0.00071	0.00000	-0.00047	0.00000	-0.00028
		3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
		4	0.00000	-0.01220	0.00000	-0.00657	0.00000	-0.00437
	11	1	0.00000	0.99998	0.00000	0.67476	0.00000	0.12522
		2	0.00000	-0.00117	0.00000	-0.00079	0.00000	-0.00015
		3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
		4	0.00000	-0.01920	0.00000	-0.01144	0.00000	-0.00213
9	11	1	0.00000	0.99998	0.00000	0.67476	0.00000	0.12522
		2	0.00000	-0.00117	0.00000	-0.00079	0.00000	-0.00015
		3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
		4	0.00000	-0.01920	0.00000	-0.01144	0.00000	-0.00213
	12	1	0.00000	0.94703	0.00000	0.65663	0.00000	0.00000

Mask 2.2 Buckling Shapes

3.4.3 Mask 2.3 Critical Load Factors

This mask shows the results of the *Critical Load Factor* and the corresponding *Magnification Factor* of the entire system relating to the buckling shape. The equation for the magnification factor α is:

$$\alpha = \frac{1}{1 - \frac{1}{\eta_{Ki}}} \, .$$



Mask 2.3 Critical Load Factors

The α magnification factor is used in the equation $M^{II} = \alpha \, . \, M^{I}$, where

M^{I} is the moment according to Theory I Order, and

M^{II} is the moment according to Theory II Order.

This equation is valid only if the bending line is similar to the buckling shape load and $\eta_{\text{-Crit}}$ is greater than 1.

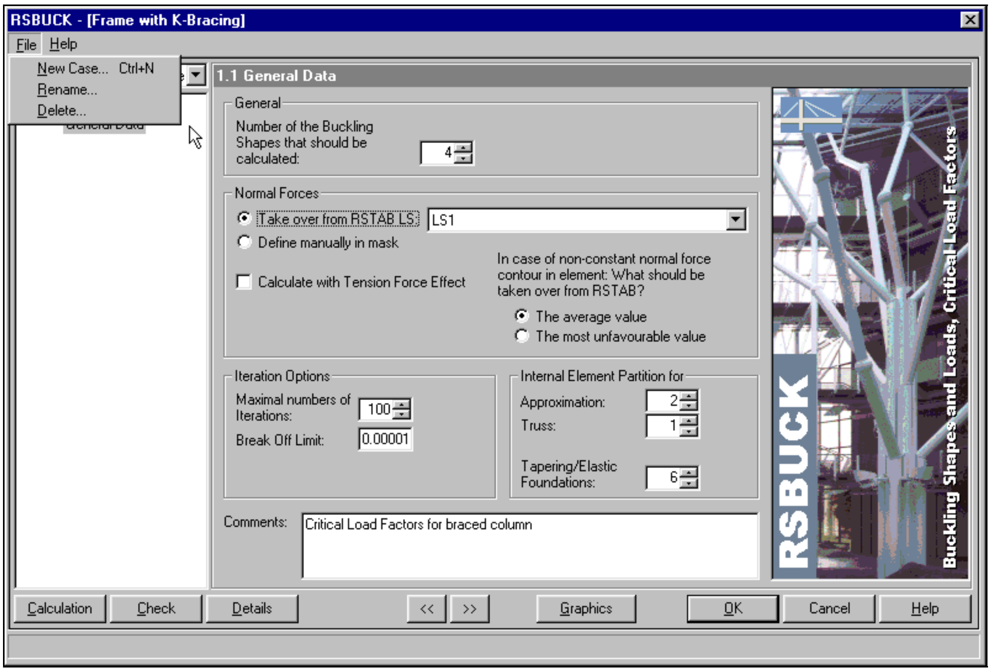
3.5 Menus

The menus contain the necessary functions to work with RSBUCK Cases and results.

Activate a menu by clicking on a menu title or simultaneously pressing the [Alt] key and the underlined letter in the menu title. Activate functions within the menus the same way.

3.5.1 File

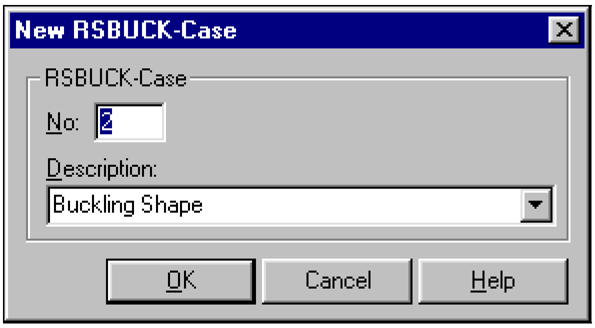
...lets you work with RSBUCK Cases.



Menu - File

New Case[Ctrl+N]

...lets you create a new RSBUCK case.

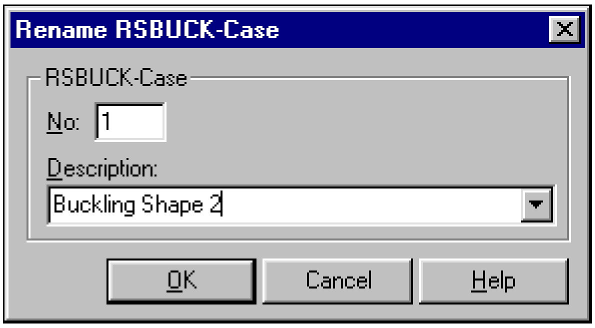


New RSBUCK Case

Give each *New RSBUCK Case* a *No.* and *Description*. Click on the [Downward Arrow] for a list of all existing descriptions. You may use one of these descriptions. [OK] creates the new case.

Rename

...lets you rename the *Description* and select a different *No.* for an existing RSBUCK case.

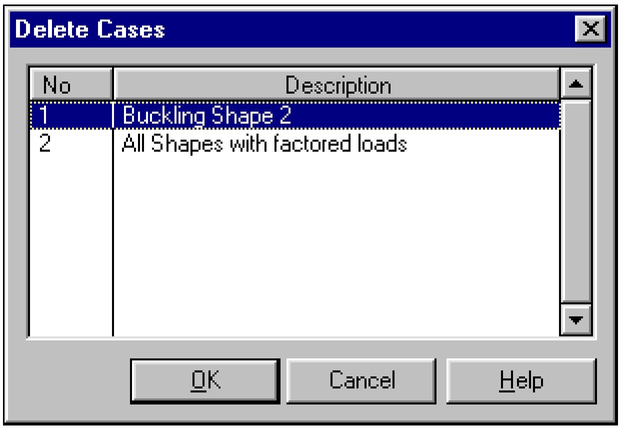


Rename RSBUCK Case

It is important to assign a number not already in use.

Delete

...shows all existing RSBUCK cases in a list.

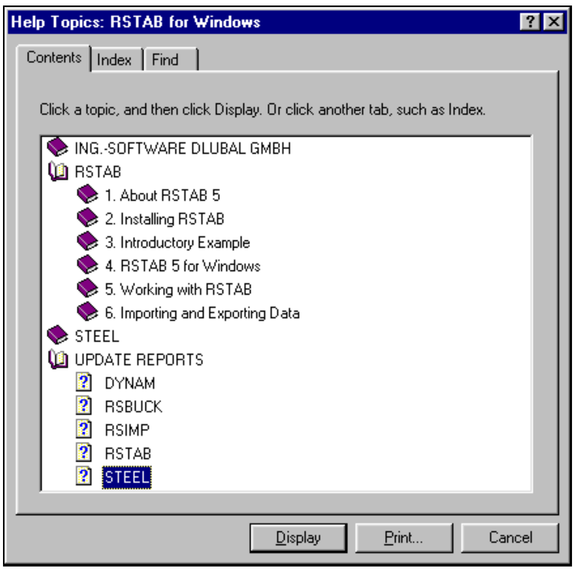


Delete Cases

Delete a case by clicking on the description and then on [OK].

3.5.2 Help

...opens the online help system.

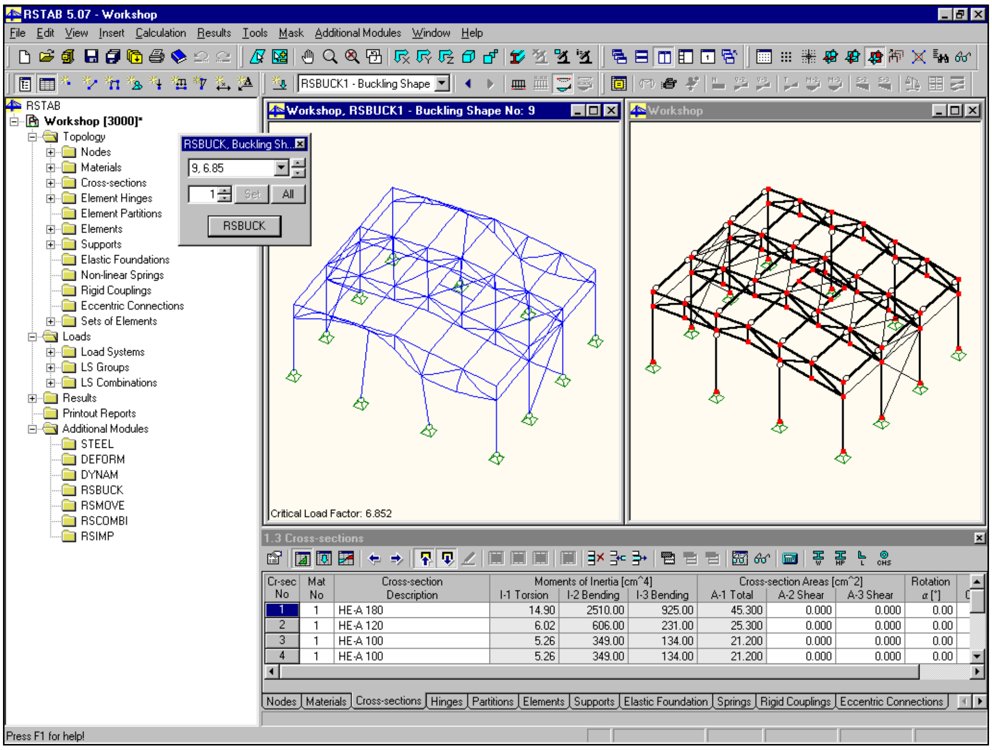


Help System of RSTAB and RSBUCK

4. Results

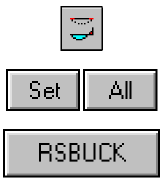
4.1 Screen Views

Following a successful calculation, you can graphically view the results with the [Graphics] button. The current RSBUCK case is automatically put in graphic form.



Cr-sec No	Mat No	Cross-section Description	Moments of Inertia [cm^4] I-1 Torsion	I-2 Bending	I-3 Bending	Cross-section Areas [cm^2] A-1 Total	A-2 Shear	A-3 Shear	Rotation α [°]
1	1	HE-A 180	14.90	2510.00	925.00	45.300	0.000	0.000	0.00
2	1	HE-A 120	6.02	606.00	231.00	25.300	0.000	0.000	0.00
3	1	HE-A 100	5.26	349.00	134.00	21.200	0.000	0.000	0.00
4	1	HE-A 100	5.26	349.00	134.00	21.200	0.000	0.000	0.00

Viewing Results Graphically

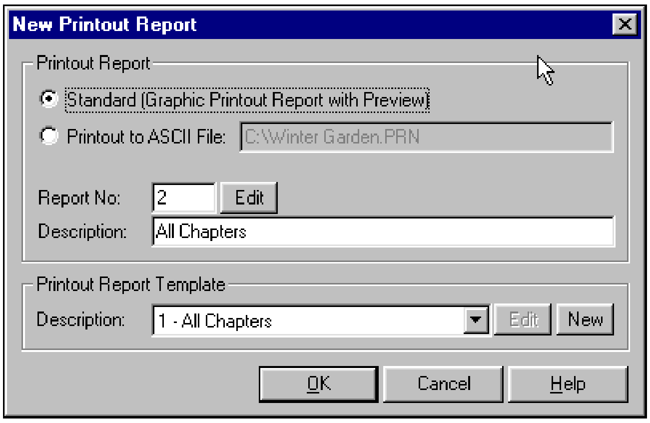


Activate the RSBUCK case in the *View Results* drop down list box in RSTAB for the option of viewing the first buckling shape results in the RSTAB working window. A smaller *RSBUCK, Buckling Shapes* floating window will open at the same time. In the drop-down list box select which buckling shape you want. The lower input field is used to enter the distance of the buckling shape lines from the elements. Click on the [Set] button to apply the edited factor for the line distance in the working window. While using the small arrow buttons on the right side of the edit field, the [Set] button is not available. It becomes available only when the number in the input field changes. [All] applies the value on all windows. [RSBUCK] takes you back to the RSBUCK module.

The [Print] button prints the graphic results immediately or integrates the results in the printout report.

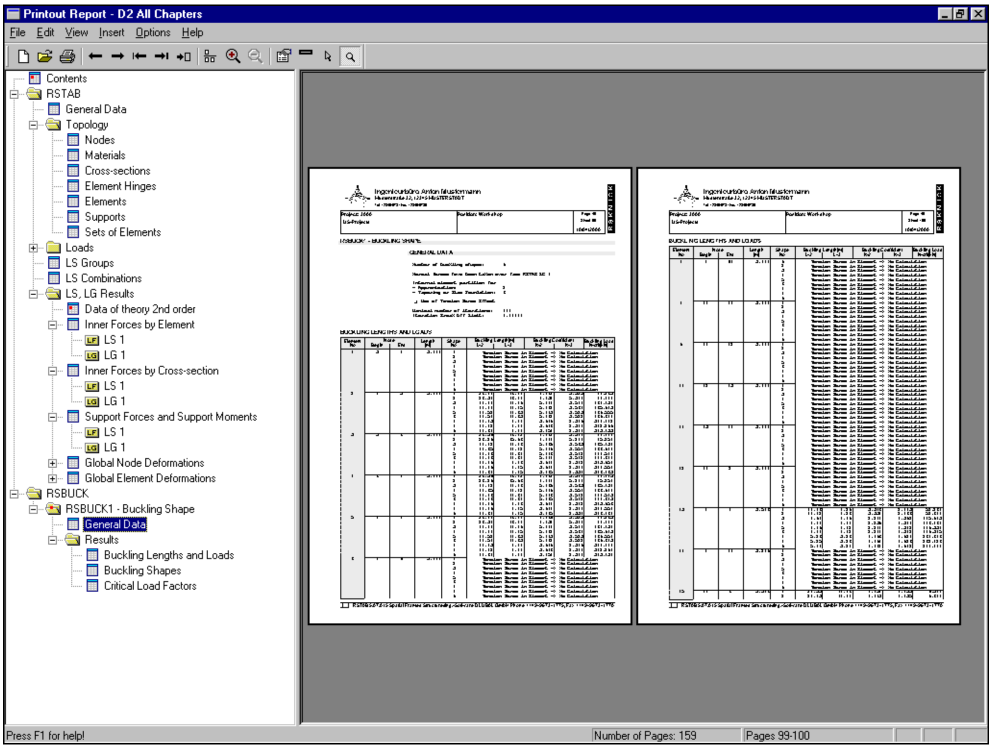
4.2 Printing

To print the numerical results, return to RSTAB and open an existing [Printout Report] or create a new one as described in the RSTAB manual.



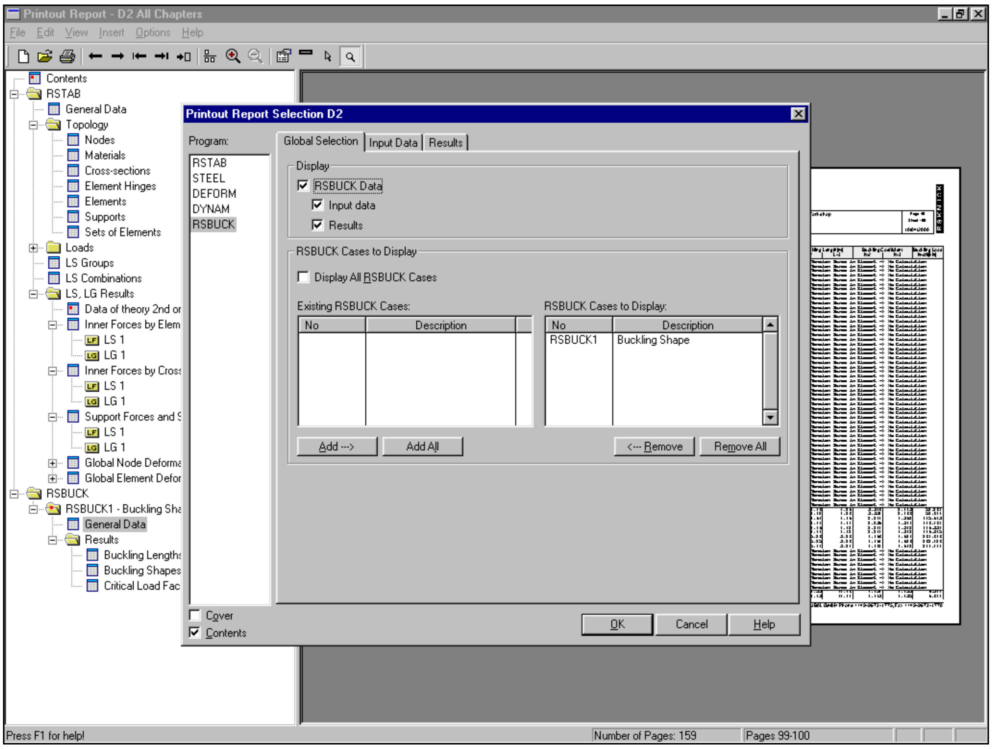
New Printout Report

Remember that the printout report is an entire unit of all data from RSTAB, RSBUCK, and other modules. Make your printout report selections with respect to the amount of data.

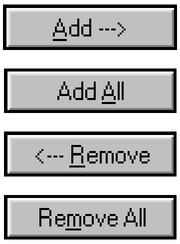


RSBUCK Data and Results in Printout Report

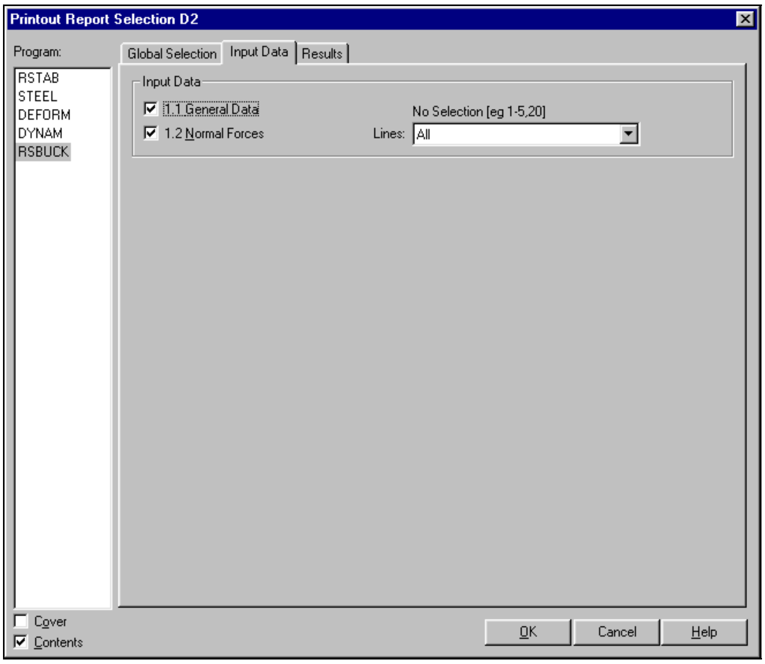
The printout report has all editing and organization possibilities described in the RSTAB Manual. The *Selection* dialogue contains additional options for printing the RSBUCK data. Click on the [Selection] button in the RSTAB printout report to open the *Selection Printout Report* dialog. Once there, click on RSBUCK from the list of *Programs* to the left to be able to edit the RSBUCK selection folders.



RSBUCK Selection – Global Selection

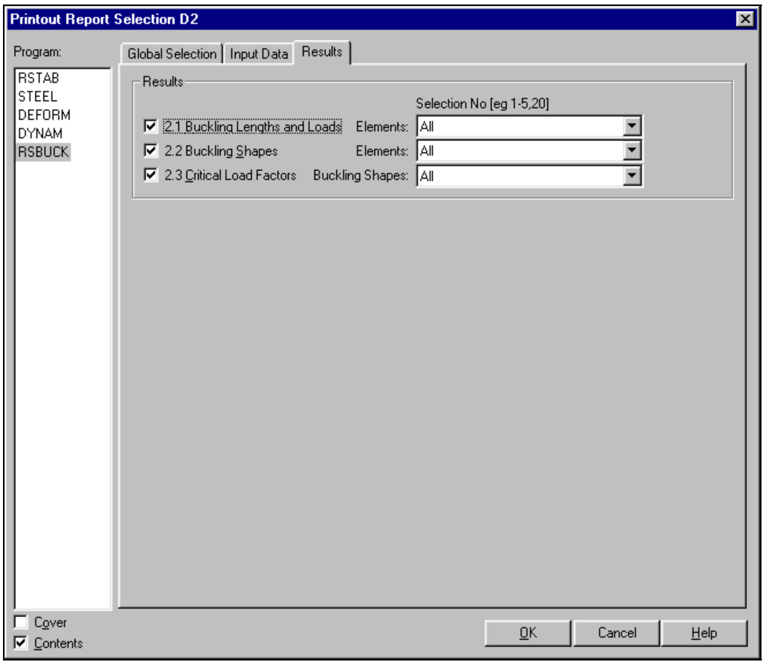


In the ***Global Selection*** folder, select the *Display* of *RSBUCK Input Data* and/or *Results.* Under *RSBUCK Cases to Display,* you can check the box to *Display All RSBUCK Cases,* or make specific selections by moving *Existing RSBUCK Cases* on the left to *RSBUCK Cases to Display* on the right. To move cases from one list to the other, highlight a case by clicking on it. Then click on the [Add >], [Add All], [Remove] or [Remove All] buttons. Checking the *Show Contents* box in the lower left mask corner will display the entire table of contents in the printout report.



RSBUCK Selection – Input Data

In the ***Input Data*** folder you can select information from the *General Data* and *Normal Forces* for the printout report. You can also specify single *Lines* from the normal forces mask tables. Just enter the line numbers under *No. Selection* or use the [Downward Arrow] button next to the input field.



RSBUCK Selection - Results

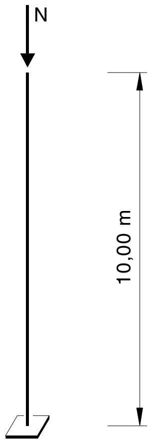
In the ***Results*** folder you can select data from masks 2.1-2.3 for inclusion in the printout report. Use the same procedure as for the input data folder.

In each folder, the editing is confirmed and the dialog closed with the [OK] button. [Cancel] closes the dialog without accepting any changes.

5. Examples

5.1 Euler´s Case I

With the 3D model in the picture below, determination of the buckling value will be carried out and compared with the exact analytical solution.
The structure is a cantilever column loaded with a normal force at the unsupported end. The K-value for such a structure (Euler´s Case I) is 2.

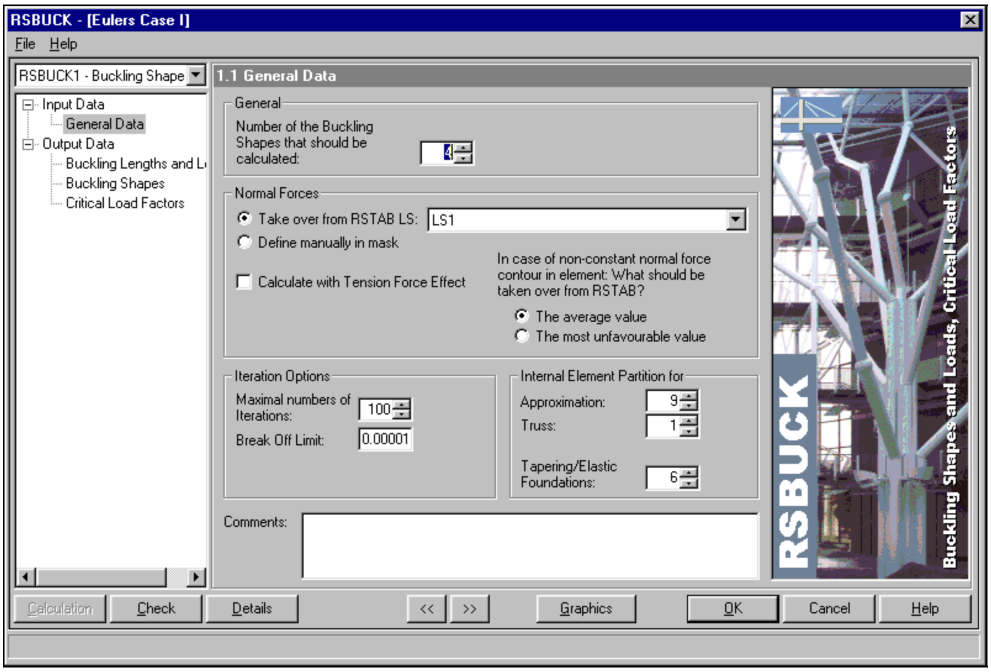


Euler´s Case I Model

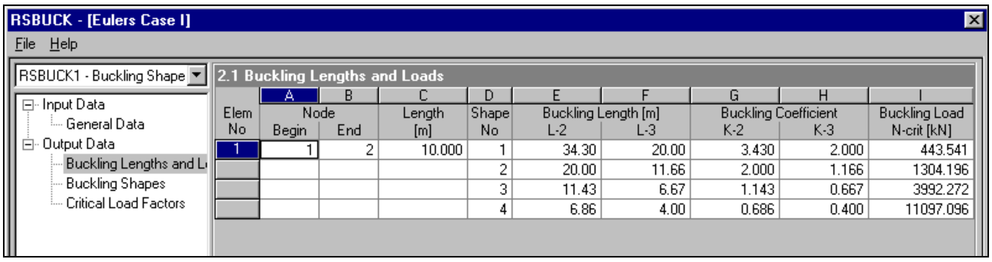
Restrained support under normal force: N = 100 kN
Material: Steel St 37 Profile: HE-B 300
Iy = 25170 cm4 Iz = 8560 cm4

$$P_{crit} = \frac{EI_z \cdot \pi^2}{k^2} = \frac{21000 \cdot 8560 \cdot \pi^2}{(2 \cdot 1000)^2} = 443{,}54\, kN$$

The input and results of this example are documented in the following pictures.



Mask 1.1 General Data



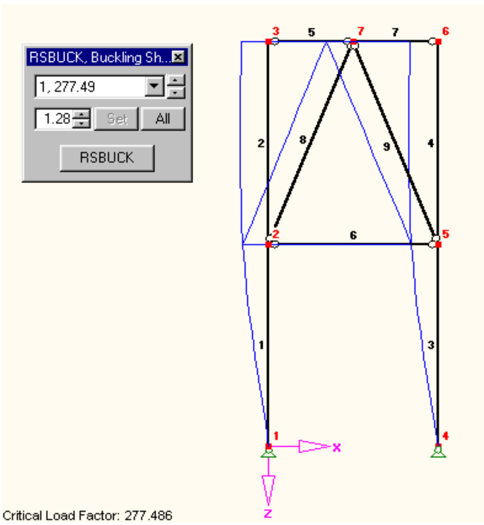
	A	B	C	D	E	F	G	H	I
Elem No	Node Begin	End	Length [m]	Shape No	Buckling Length [m] L-2	L-3	Buckling Coefficient K-2	K-3	Buckling Load N-crit [kN]
1	1	2	10.000	1	34.30	20.00	3.430	2.000	443.541
				2	20.00	11.66	2.000	1.166	1304.196
				3	11.43	6.67	1.143	0.667	3992.272
				4	6.86	4.00	0.686	0.400	11097.096

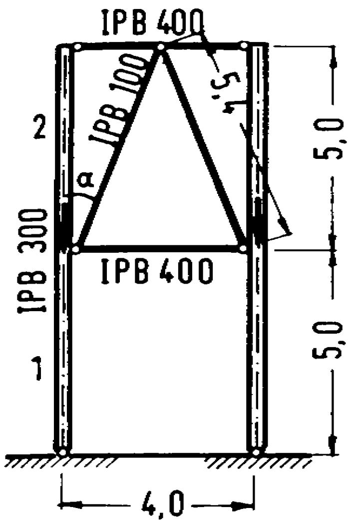
Mask 2.1 – Buckling Lengths and Loads

RSBUCK calculates a critical Buckling Load N-crit of 443.541 kN. To increase the exactness of the result, return to the *1.1 General Data* mask and increase the *Internal Element Partition for Approximation* to 9.

5.2 Frame with K-Bracing

In the picture below, determination of the buckling value will be carried out and compared

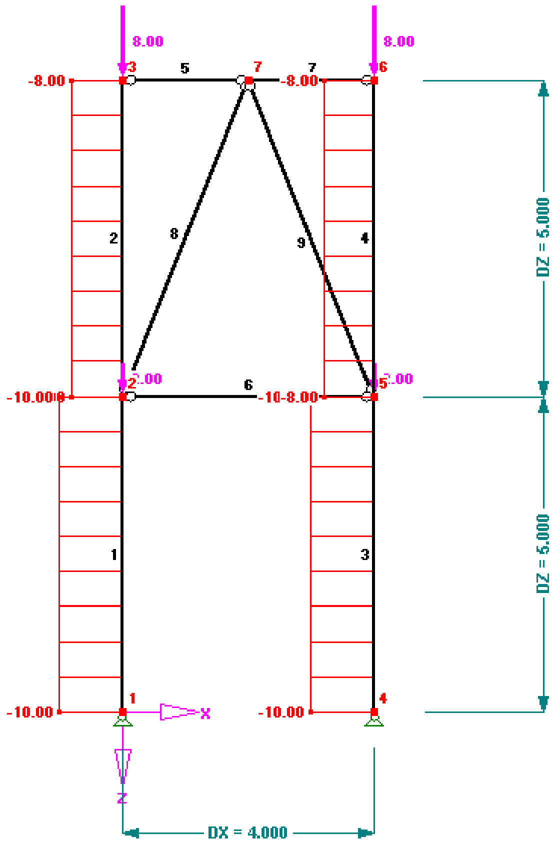




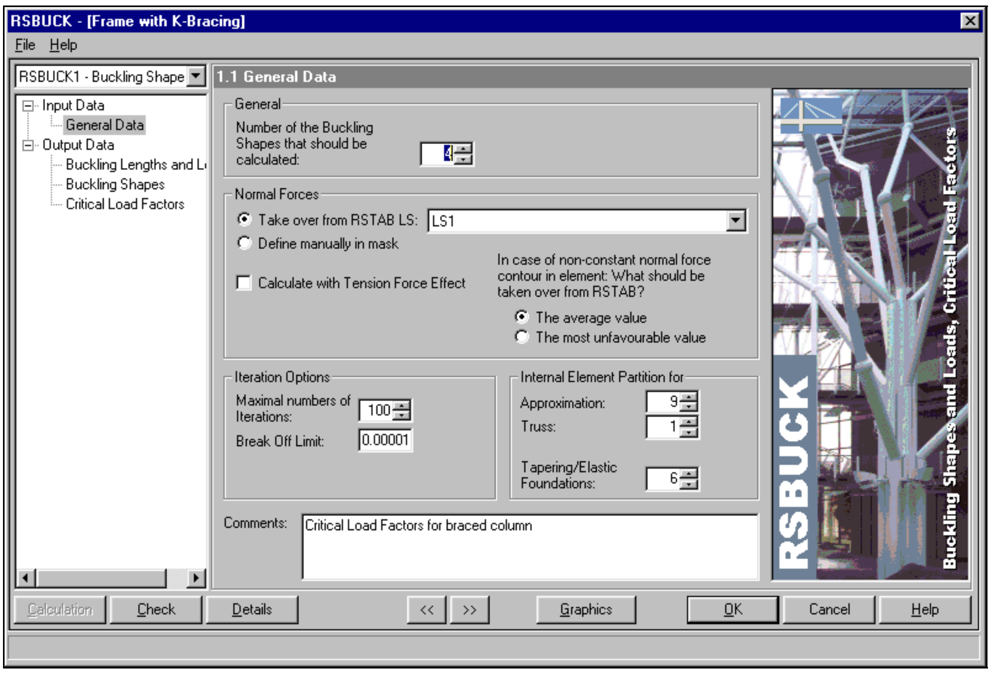
with the example in literature reference [1].

Steel Frame with K-Bracing taken from example 5.47, page 395, Literature Reference [1]

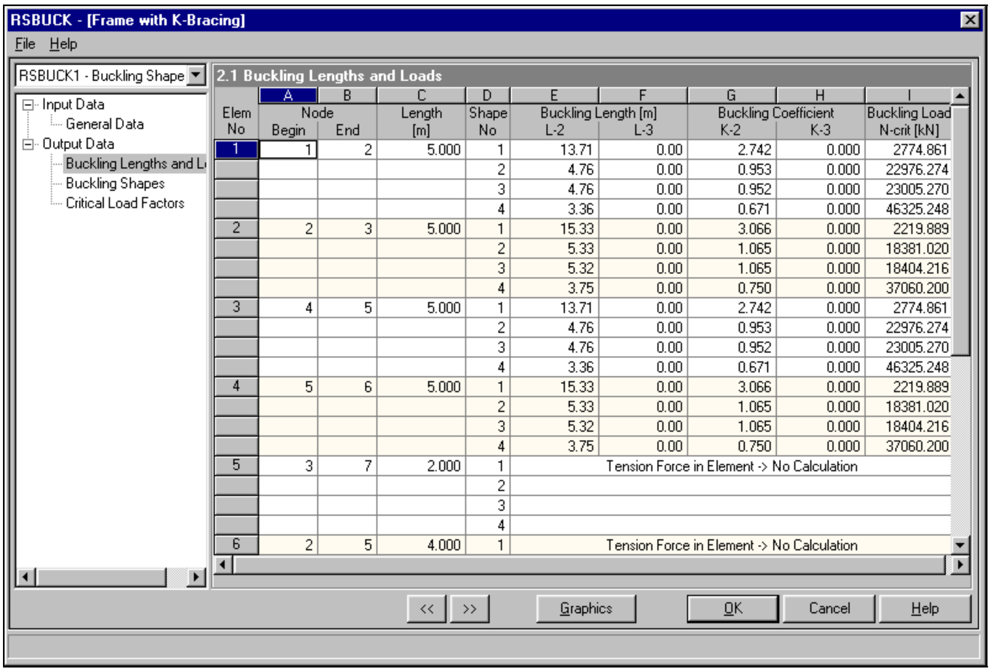
The input in RSTAB and RSBUCK is documented in the following pictures:



Input and Results display in RSTAB



Mask 1.1 General Data in RSBUCK



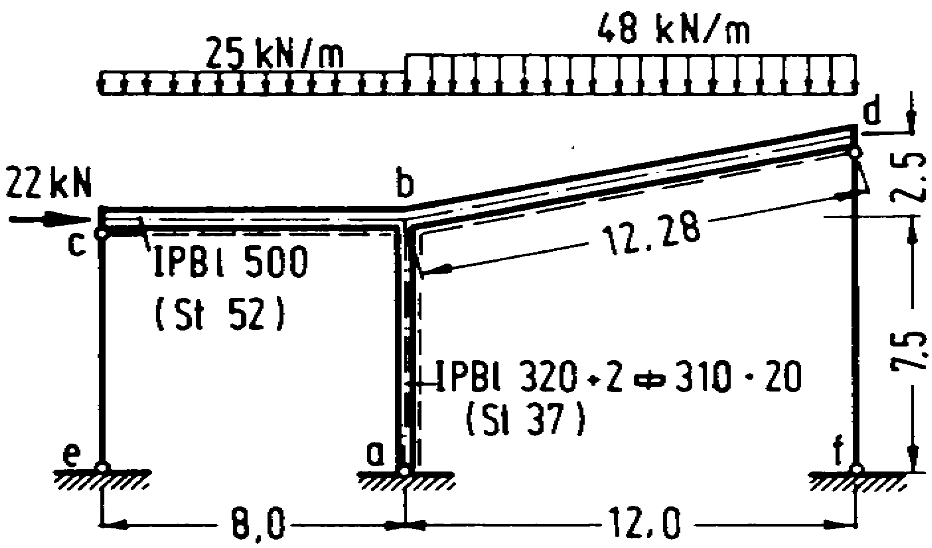
Elem No	Node Begin (A)	Node End (B)	Length [m] (C)	Shape No (D)	Buckling Length [m] L-2 (E)	Buckling Length [m] L-3 (F)	Buckling Coefficient K-2 (G)	Buckling Coefficient K-3 (H)	Buckling Load N-crit [kN] (I)
1	1	2	5.000	1	13.71	0.00	2.742	0.000	2774.861
				2	4.76	0.00	0.953	0.000	22976.274
				3	4.76	0.00	0.952	0.000	23005.270
				4	3.36	0.00	0.671	0.000	46325.248
2	2	3	5.000	1	15.33	0.00	3.066	0.000	2219.889
				2	5.33	0.00	1.065	0.000	18381.020
				3	5.32	0.00	1.065	0.000	18404.216
				4	3.75	0.00	0.750	0.000	37060.200
3	4	5	5.000	1	13.71	0.00	2.742	0.000	2774.861
				2	4.76	0.00	0.953	0.000	22976.274
				3	4.76	0.00	0.952	0.000	23005.270
				4	3.36	0.00	0.671	0.000	46325.248
4	5	6	5.000	1	15.33	0.00	3.066	0.000	2219.889
				2	5.33	0.00	1.065	0.000	18381.020
				3	5.32	0.00	1.065	0.000	18404.216
				4	3.75	0.00	0.750	0.000	37060.200
5	3	7	2.000	1	Tension Force in Element -> No Calculation				
				2					
				3					
				4					
6	2	5	4.000	1	Tension Force in Element -> No Calculation				

Mask 2.1 Buckling Lengths and Loads in RSBUCK

D2/D1 = 0.8	→	Literature:	RSBUCK:
		β1 = 2.73	β1 = 2.74
		β2 = 3.05	β2= 3.07

5.3 Frame with Hinged Columns

The following picture shows the determination of the middle column's effective length co-efficient, comparing RSBUCK with literature reference [1].

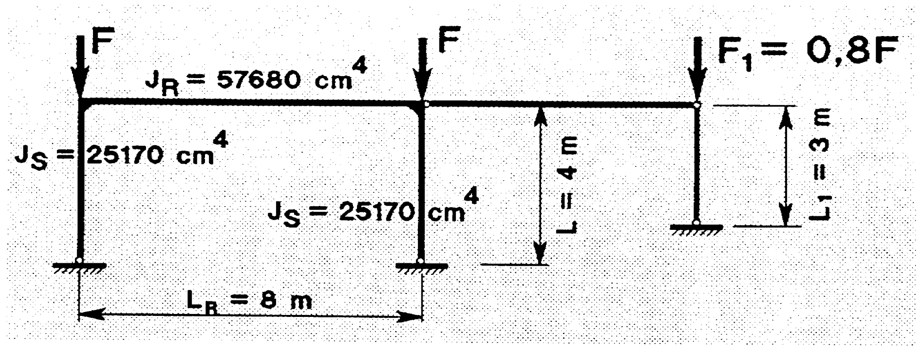


Single-hip Frame with Hinged Columns taken from Example 72, page 418, Literature Reference [1]

Literature:	RSBUCK:
β3 = 2.48	β3 = 2.43

5.4 Frame with a Hinged Column

This example shows a good concurrence of RSBUCK analysis with an equation from literature.

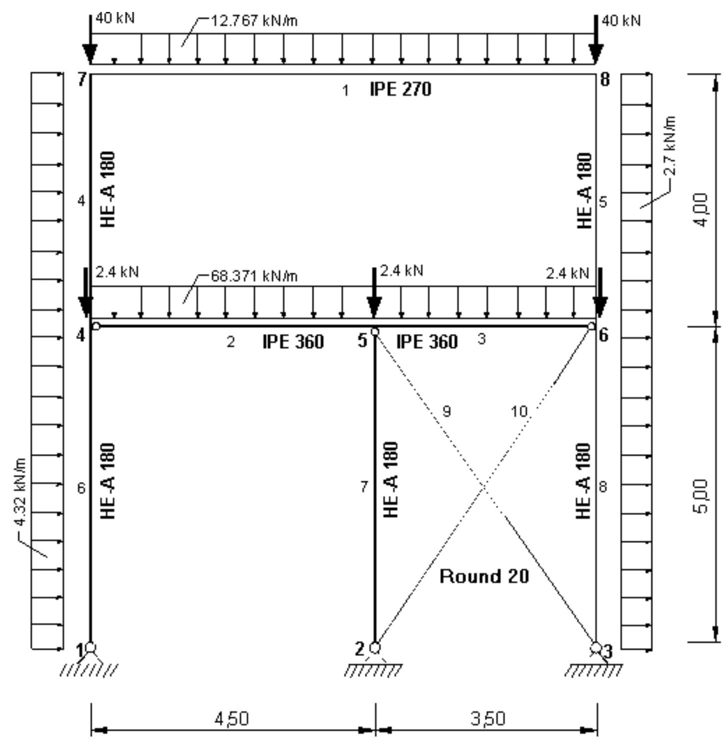


Frame with a Hinged Column taken from page Knick 18, Literature Reference [5].

Literature:	RSBUCK:
$\beta = 2.8$	$\beta = 2.785$

5.5 Framed Structure

A 2D framed structure according to the picture below will be examined for buckling.



Framed Structure

In this example, the lowest critical load factor (Eigenvalue) results on the uncoupled No. 7 hinged element. That means the first failing element is element no. 7. The failure is local, since it is only a single element. The second Eigenvalue shows the global failure shape of the entire system.

RSBUCK determines the critical load (Buckling Load N_{crit}) of element 7 as 2081.13 kN. A calculation for Euler´s case 2 results in:

$$N_{crit} = \frac{EI \cdot \pi^2}{k^2} = \frac{21000 \cdot 2510 \cdot \pi^2}{500^2} = 2080.91\, kN$$

The difference is only 0.01%.

Appendix: Literature Reference

[1] Petersen, Chr.:
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[3] Hünersen, G.; Fritsche, E.:
Stahlbau in Beispielen - Berechnungspraxis nach DIN 18800 Teil 1 bis Teil 3,
Werner-Verlag Düsseldorf, 3. Auflage 1995

[4] Rubin, H.; Schneider, K.-J.:
Baustatik - Theorie I. und II. Ordnung
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[5] Owczarzak, H.; Stracke, M.:
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vom 02.12.94