



Tutorial

Eurocode3 Members (EN1993-1-1, 2005) Optimization. Beam Rule

Updated on: March 18th, 2024

Tested with: SDC Verifier 2023 R2

Femap version 2023.2

- This step-by-step tutorial demonstrates the functionality of SDC Verifier Optimization Tool, incorporating Beam Rule;
- Model members are Optimized based on Criteria Plot results;
- Shape Library Overview;
- Optimization Rules Overview;
- Optimization results in Tables and Plots;
- Results Comparison;
- Automatic Beam Cross-section Change
- The model change by adding Beam Properties
- Complete information on Optimization Tool may be found on our website via this link: [Optimization Tool | Help | SDC for Femap \(sdcverifier.com\)](https://sdcverifier.com)

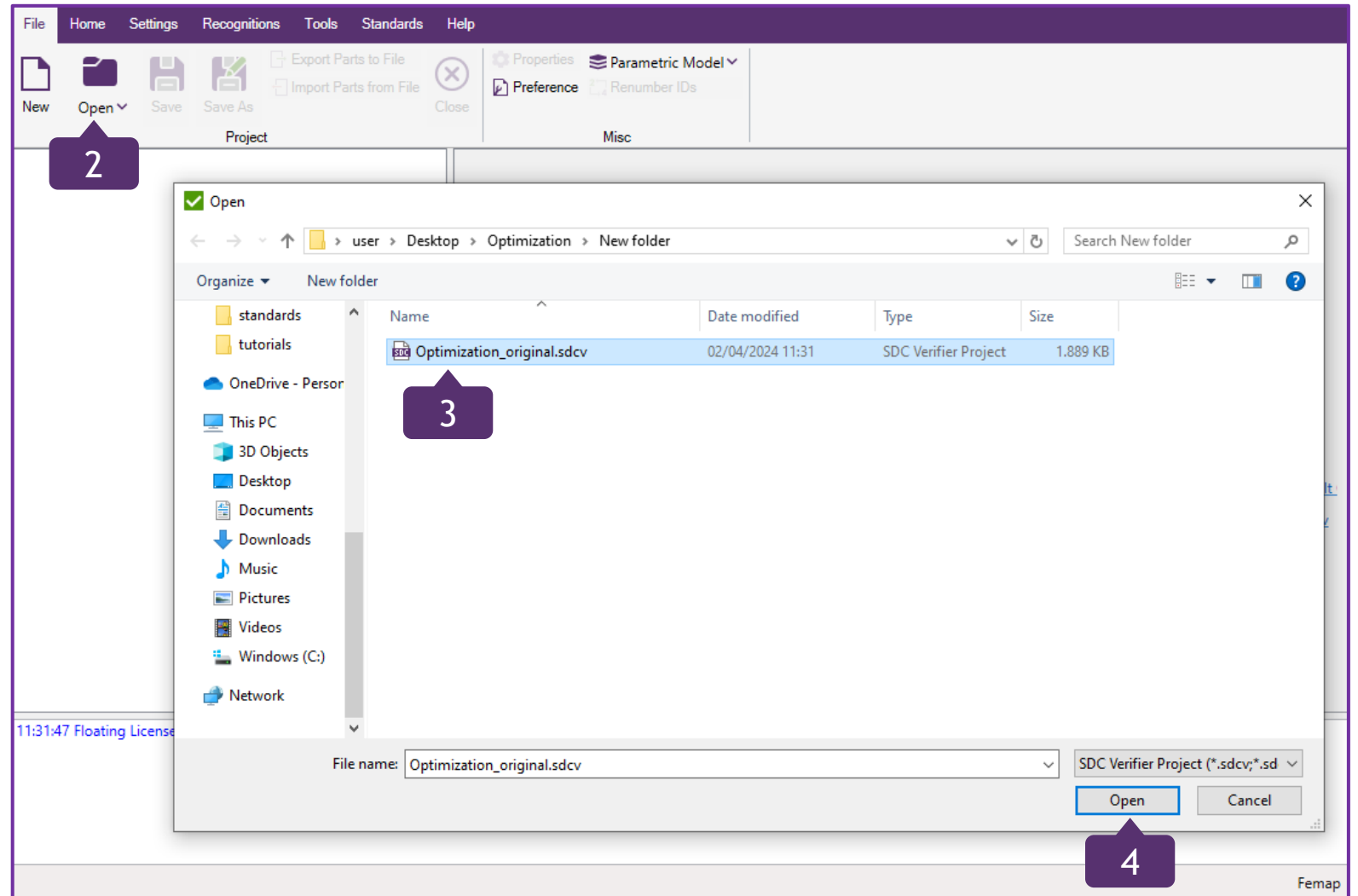
Open the Starter Model

1 Launch SDC Verifier for Femap

2 In *File* section, press *Open*

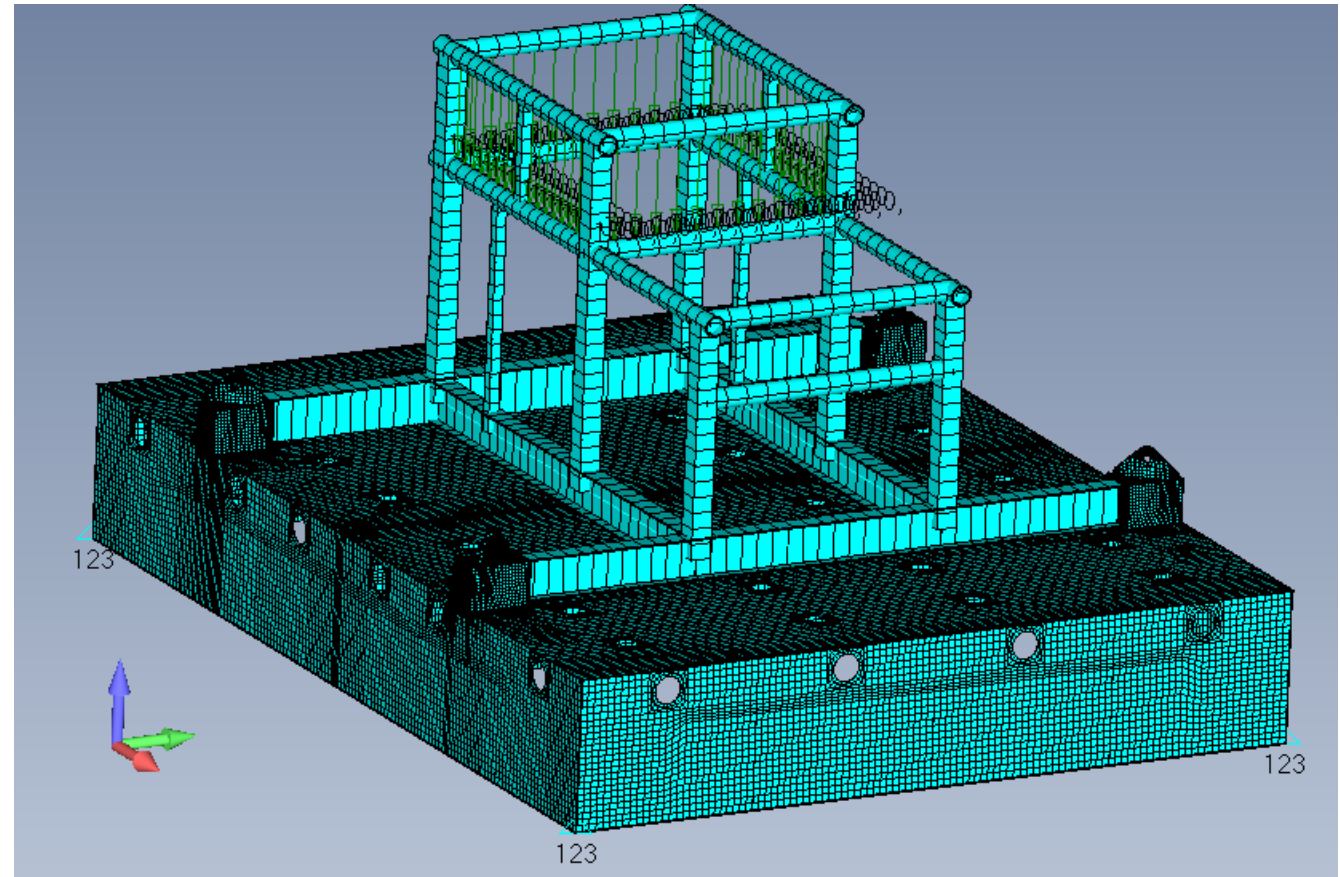
3 Select a project
Optimization_original.sdcv

4 Press *Open*



This tutorial uses a Project with predefined Individual Loads, Load Sets and Load Groups. The model contains Plate, Beam elements and Welds. Also, a relevant Standard has been previously added.

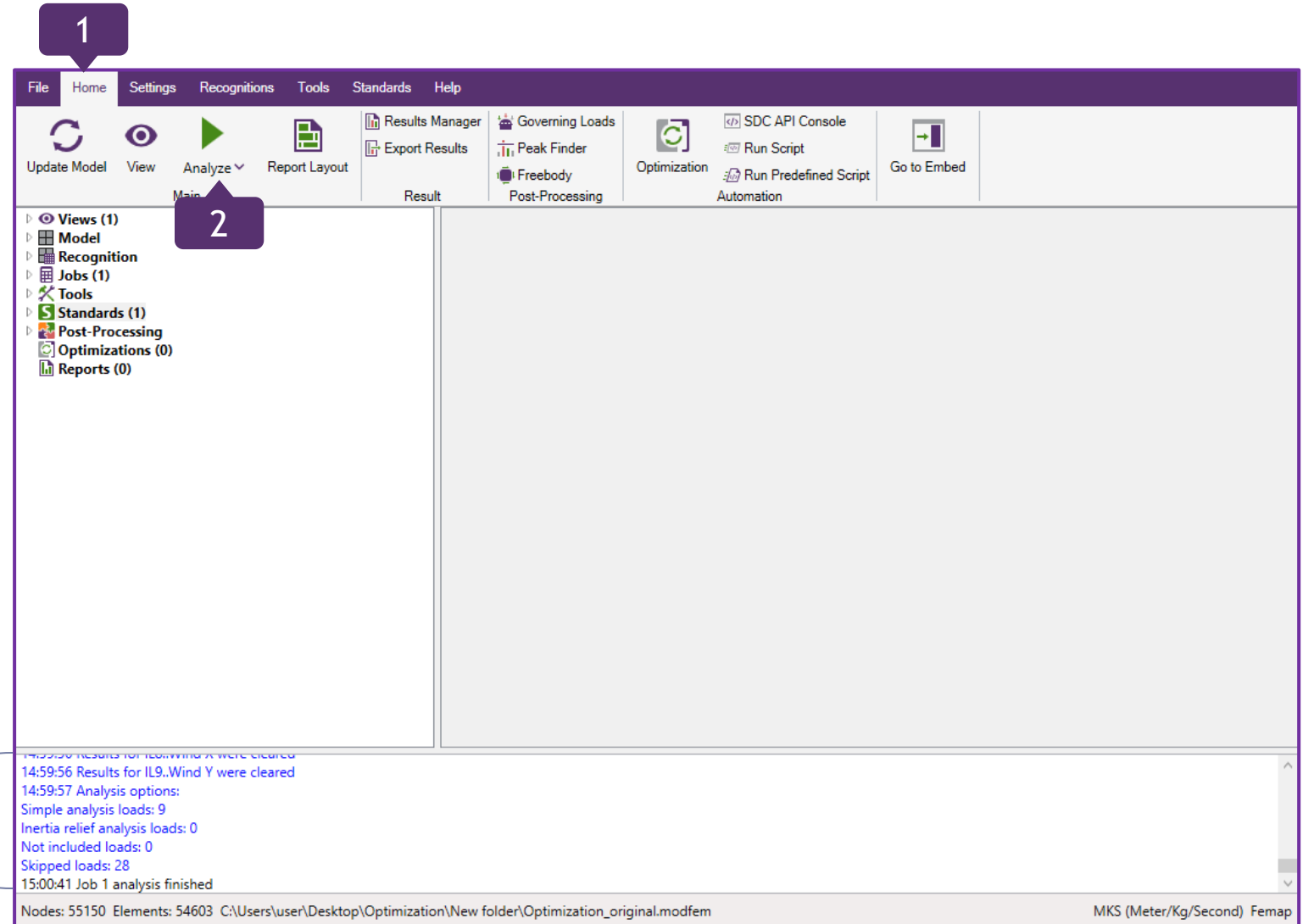
- ▲ Views (1)
 - 1..Default View
- Model
- Recognition
- ▲ Jobs (1)
 - 1..Job 1
 - Individual Loads (9)
 - Predefined Load Cases (0)
 - Load Sets (28)
 - Load Groups (5)
 - FG Fatigue Groups (0)
 - Tables (0)
 - Plots (0)
- Tools
- ▲ Standards (1)
 - 3..Eurocode3 Members (EN1993-1-1, 2005)
- Post-Processing
- Optimizations (0)
- Reports (0)



A separate Tutorial with detailed instructions on how to add, define and edit the Standard can be found via this link:
<https://sdcverifier.com/tutorials/aisc-360-10/>

1 Go to *Home* section on the Ribbon

2 Press  on the toolbar to analyze Job



Job 1 analysis started and finished.

Eurocode3 Members Criteria Plot

1

Expand Standards => 3..Eurocode3 Members (EN1993-1-1, 2005) => Checks (22) and select 22. *Buckling and Overall*

2

Execute right click on 22. *Buckling and Overall* and select *Criteria Plot*

3

Press  to select Load Group

4

In Load Type, select Load Group, and then 5..*Operations All*; Press *OK*

5

Parameter: *Uf Overall*

6

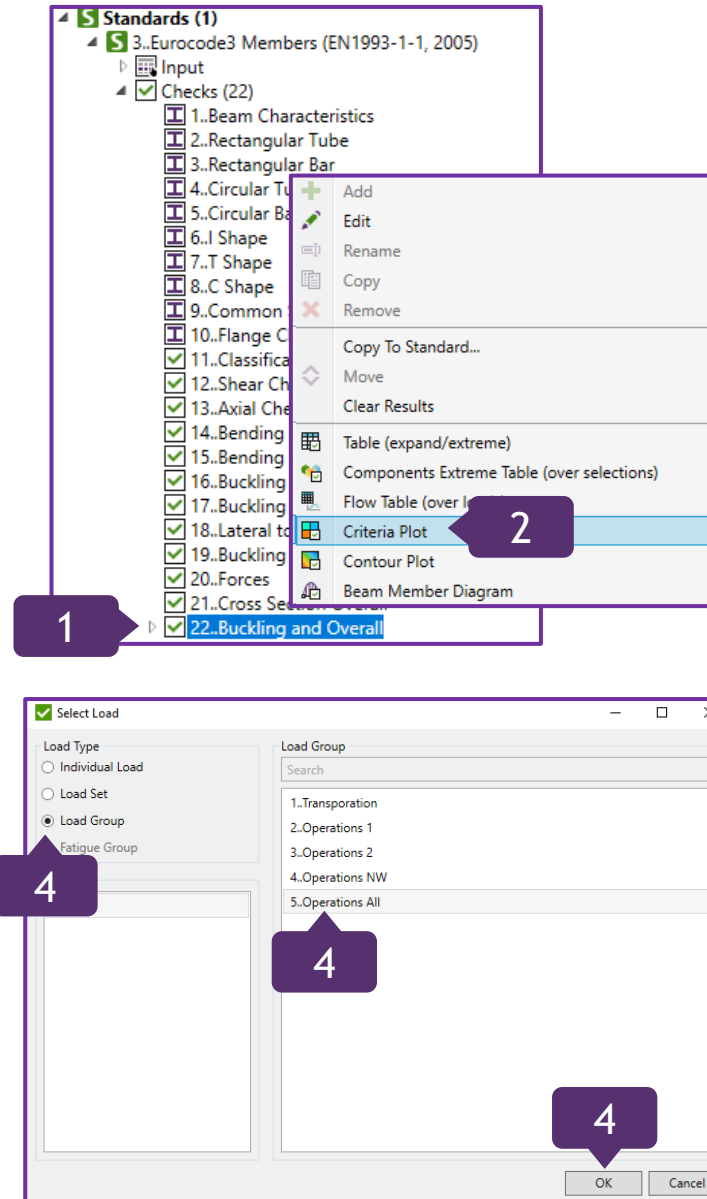
LG Parameter: *Absolute*

7

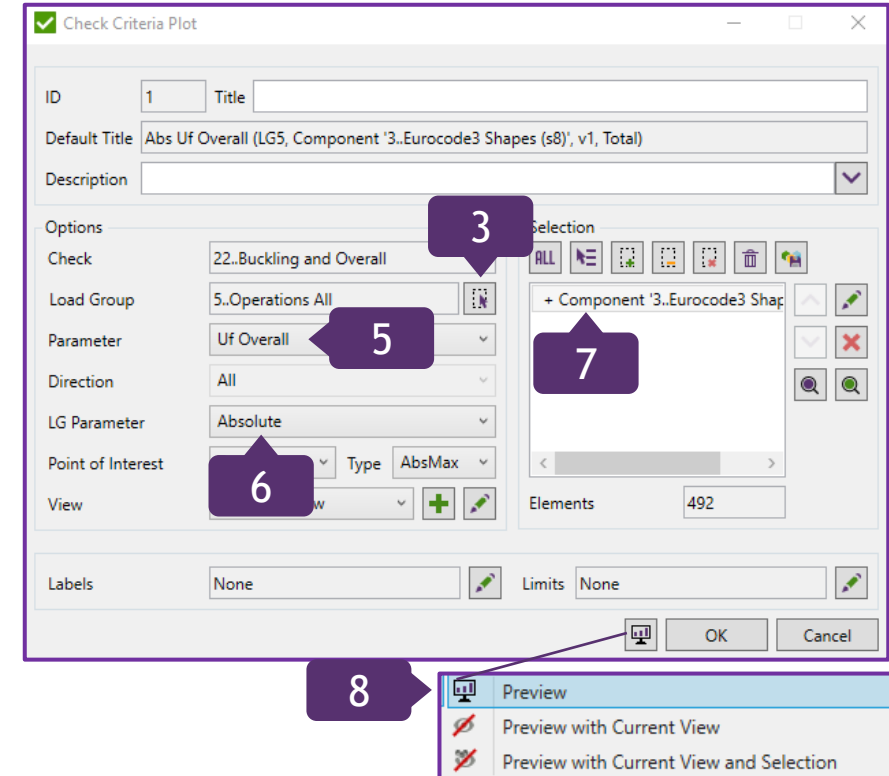
Selection: + *Component '3..Eurocode3 Shapes (s8)'*

8

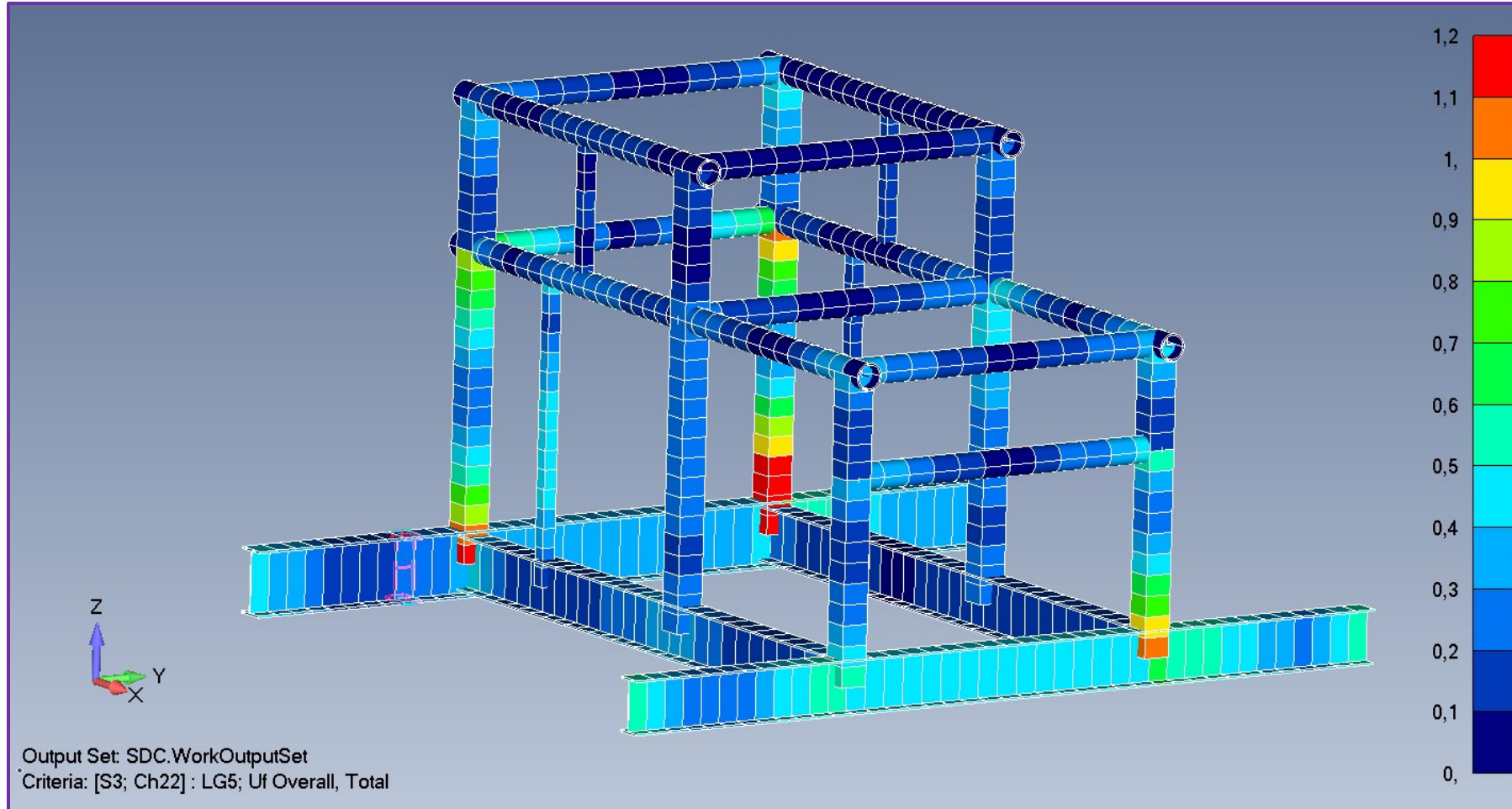
Press  and then *Preview*



The purpose of creating Criteria Plot is to preview the results of Eurocode3 Members Check and pick the members for Optimization.



The Plot has been created to see the UF Overall on Beam members.
It is displayed in Femap window.



Set Limits for Criteria Plot (Additional Functionality)

In order to single out the segments with high Utilization Factor, excluding the rest of the elements, Limits function serves for that. The settings of Check Criteria Plot from Slide 6 should remain the same.

1

In Limits, press



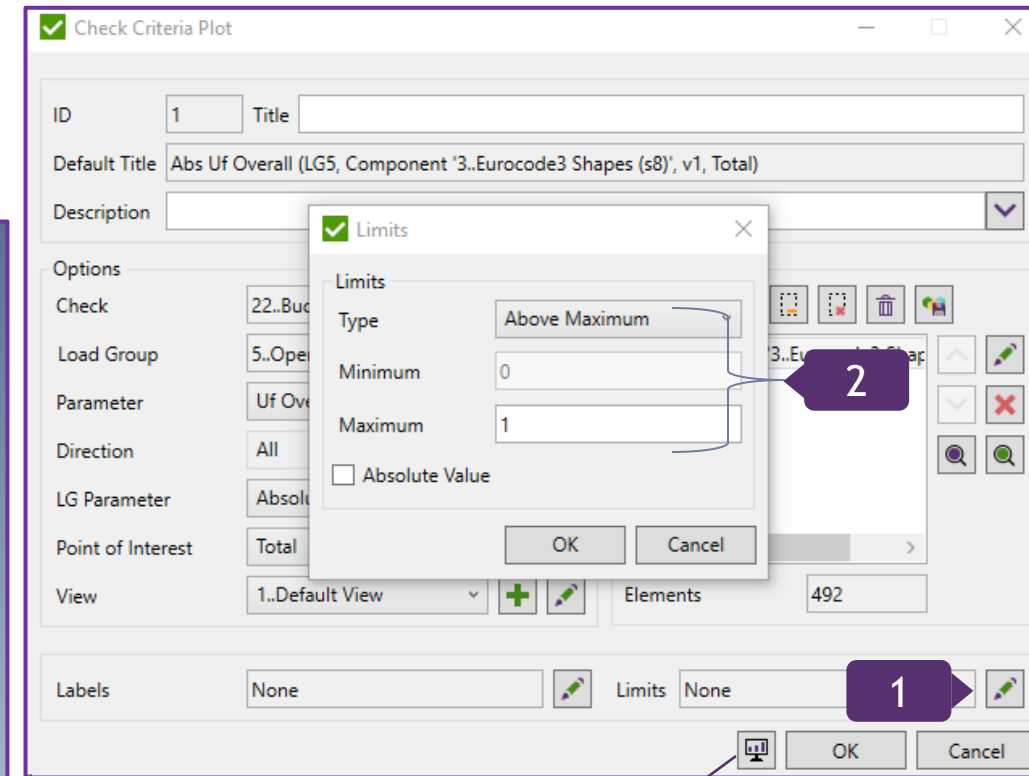
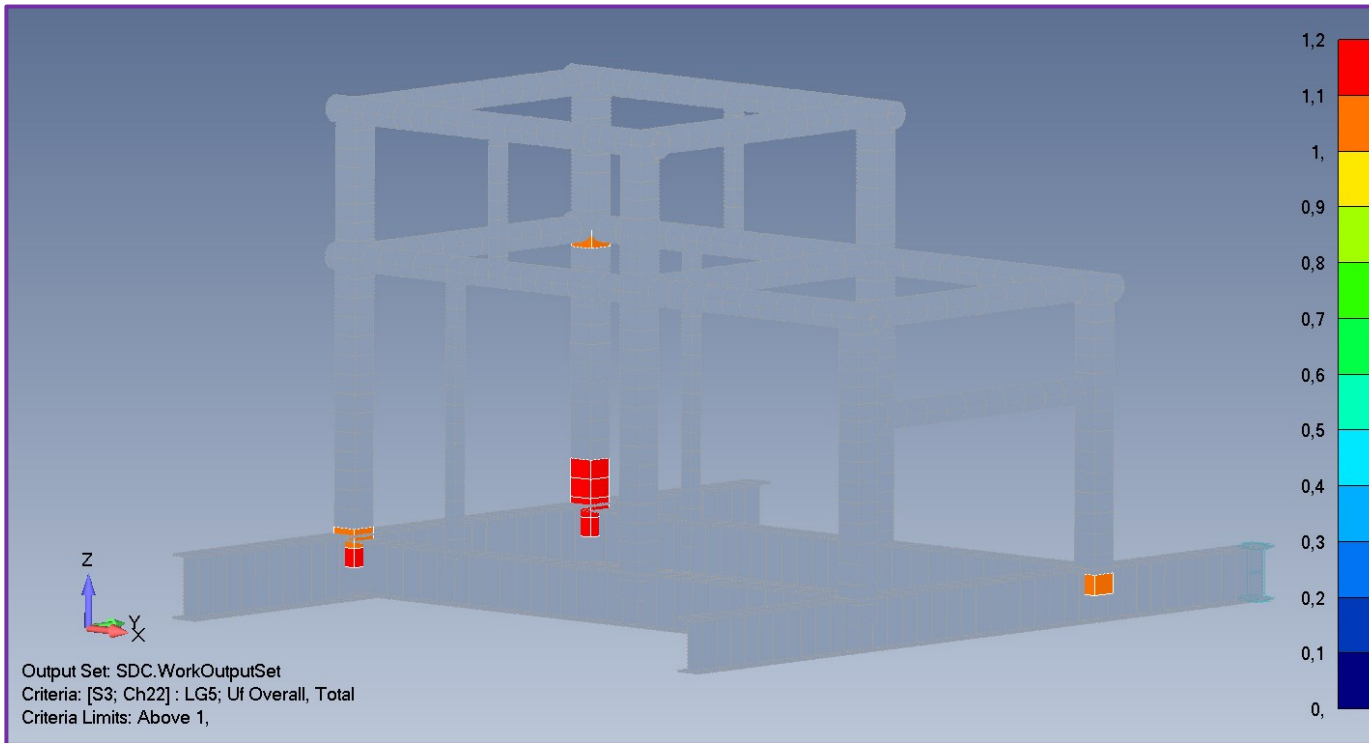
2

Type: *Above Maximum*;
Maximum: 1;
Press *OK*

3

Press  and then *Preview*

The Result



3


- Preview
- Preview with Current View
- Preview with Current View and Selection

Eurocode3 Members Criteria Plot for One Property

1

Select + Component '3..Eurocode3 Shapes (s8)' and press  to remove it

2

Press  to add Condition;
Select **Properties**

3

Select 17..Beam Square tube d=150 mm_Steel;
Press OK

4

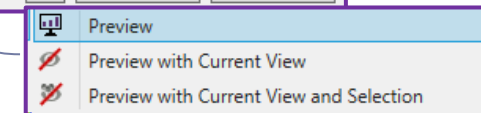
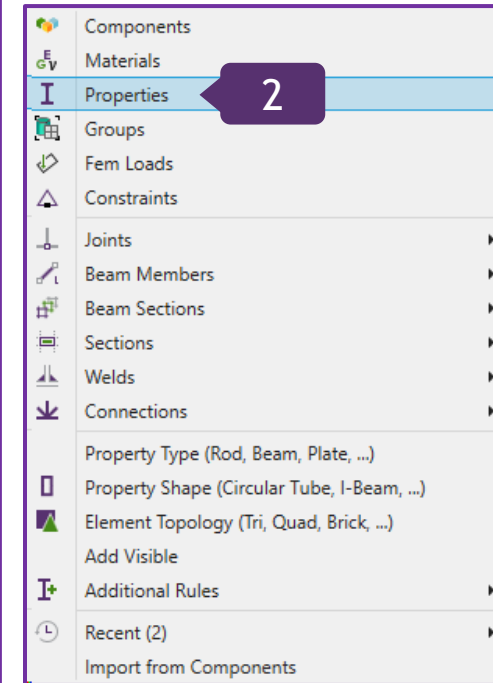
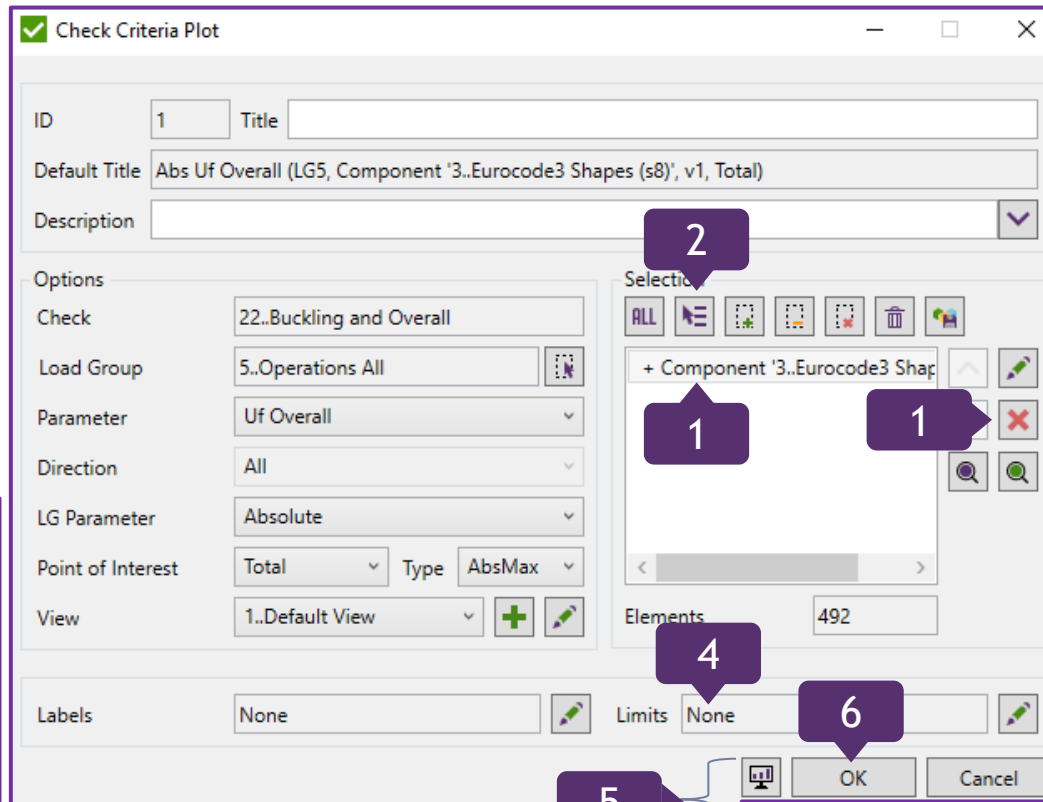
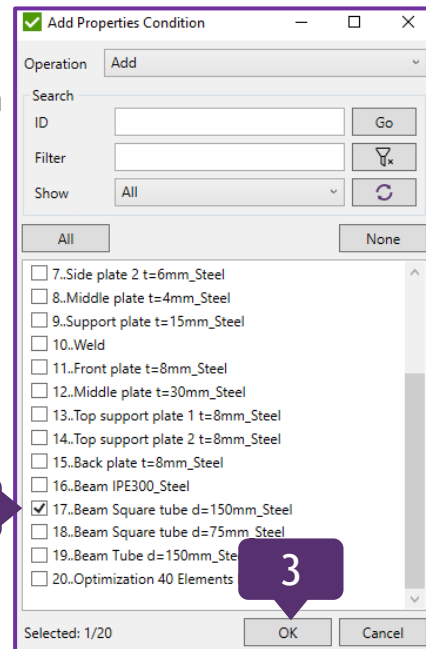
Limits: None

5

Press  and then
Preview

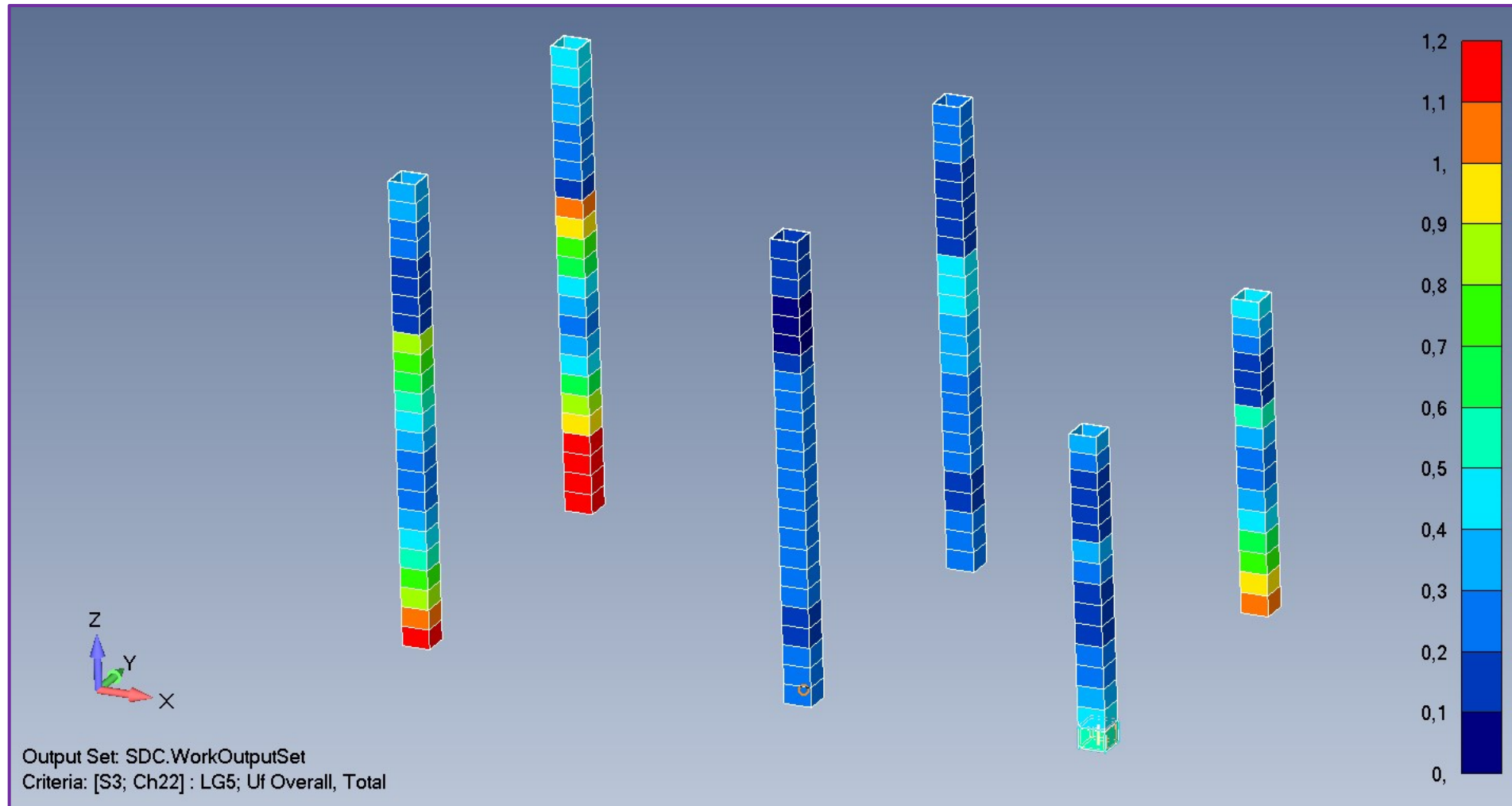
6

Press OK



Some members of 17..Beam Square tube d=150mm_Steel Property have UF Overall value above 1.
An Optimization Rule for these members will be created.

The Plot has been created to see the UF Overall for one Property.



Optimization Tool allows to take the best design decision for the structure by calculating different combinations of design input.

Optimization Rule consists of a set of conditions that represent the part of the model, the type of optimization and the referring parameters (usually, Utilization Factors) of design standards to be optimized.

The following types of the rules can be created:

Beam Rule - beam/bar element cross section, yield stress and young modulus can be optimized;

Plate Element Rule - plate/shell element thickness, yield stress and young modulus can be optimized;

Plate Buckling Rule - plate buckling plate thickness, yield stress and young modulus can be optimized;

Weld Strength Rule - weld type and dimensions (leg sizes, throat thickness etc.) can be optimized.

Note: Only one Rule of each type can be created within one optimization tool. Plate element and Plate buckling Rules cannot be created within one optimization tool.

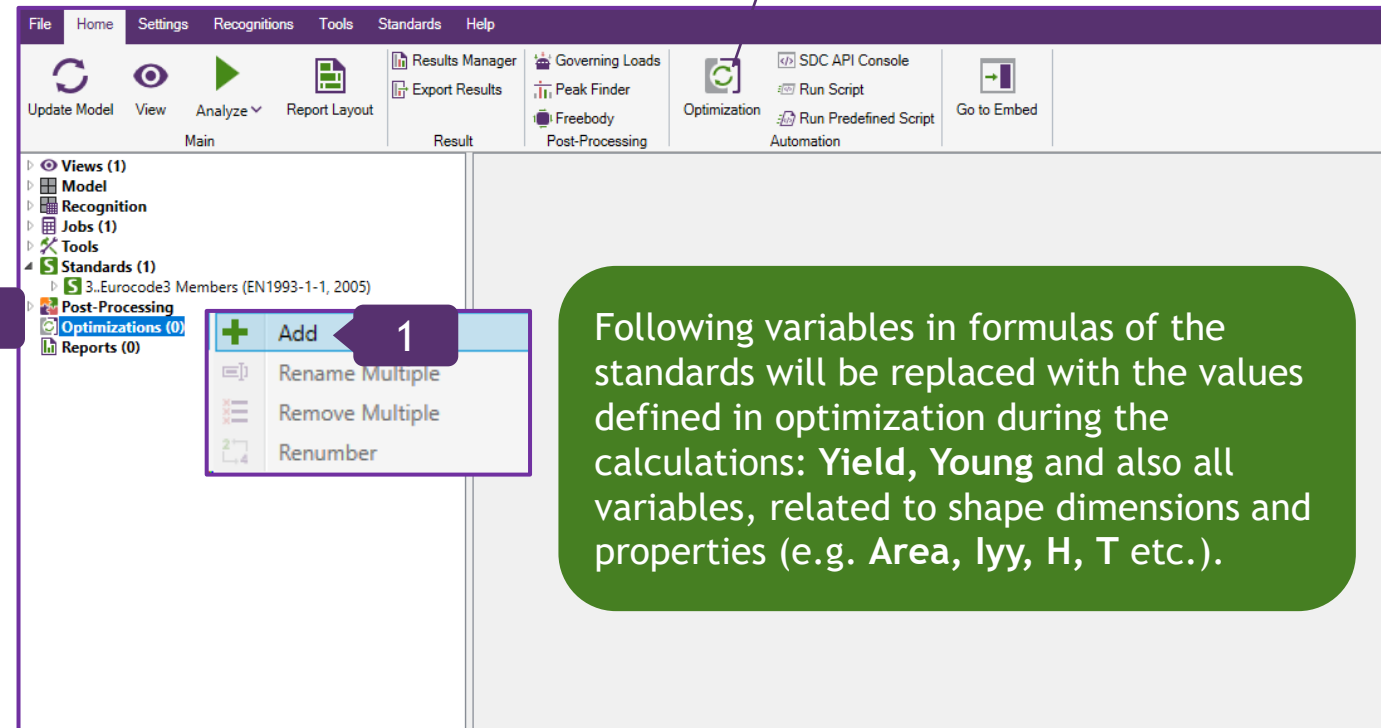
Create Optimization Rule

1 In the Model Tree, execute right click on *Optimization* and select *Add*

2 Title: *Eurocode3 Members Optimization*

3 Press  to create first *Optimization Rule*; Select *Add Beam Rule*

An alternative method of using Optimization Tool is placed in Home section of the Ribbon.



Eurocode3 Members (EN1993-1-1, 2005) Standard, along with its Checks and Parameters, can be optimized by Beam Rule.

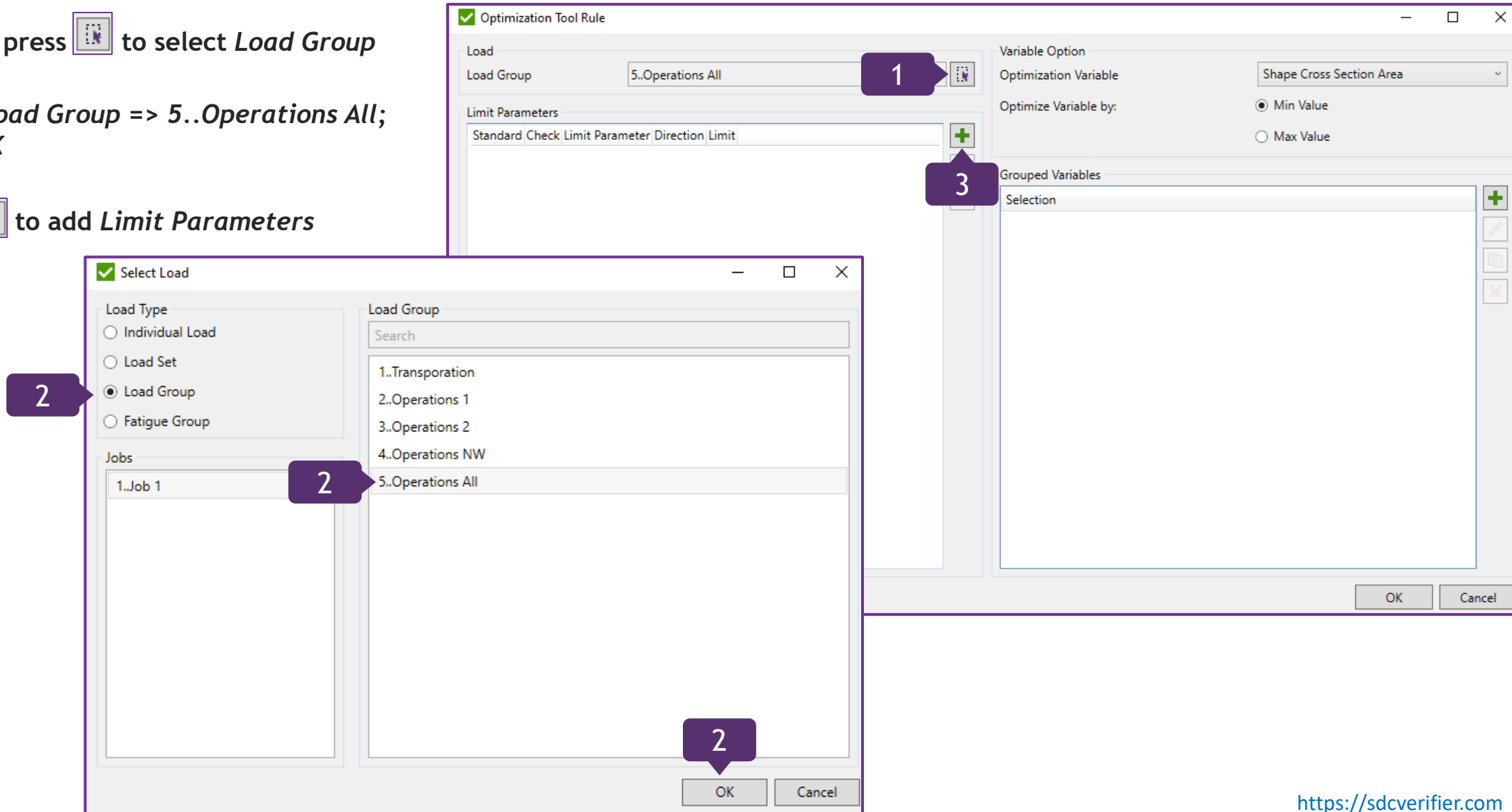
Beam Rule is used to optimize beam/bar element cross section, Yield Stress and/or Young Modulus. It is typically used for Beam Buckling Standards.

Note: If there are multiple Standards, calculated in the SDC Verifier Project, all of them will be listed in Select Limit Parameters.

1 In Load, press  to select *Load Group*

2 Select *Load Group* => *5..Operations All*;
Press *OK*

3 Press  to add *Limit Parameters*



The screenshot shows the 'Optimization Tool Rule' dialog box. The 'Load' section has 'Load Group' set to '5..Operations All', with callout 1 pointing to the selection icon. The 'Limit Parameters' section has a table with columns 'Standard', 'Check', 'Limit Parameter', 'Direction', and 'Limit', and a '+' icon with callout 3. The 'Variable Option' section has 'Optimization Variable' set to 'Shape Cross Section Area' and 'Optimize Variable by' set to 'Min Value'. The 'Grouped Variables' section has a 'Selection' list with a '+' icon. The 'Select Load' dialog box is open, showing 'Load Type' with 'Load Group' selected (callout 2), 'Jobs' with '1..Job 1' selected, and 'Load Group' with '5..Operations All' selected (callout 2). The 'OK' button is highlighted with callout 2.

Optimization Tool Rule. Eurocode3 Members (Continuation)

4

Standard: 3..Eurocode3 Members (EN1993)-1-1, 2005);
Check: 22..Buckling and Overall;
Parameter: 7..Uf Overall

5

In Limit, press 

6

Type: *Between*;
Minimum: 0 and Maximum: 1;

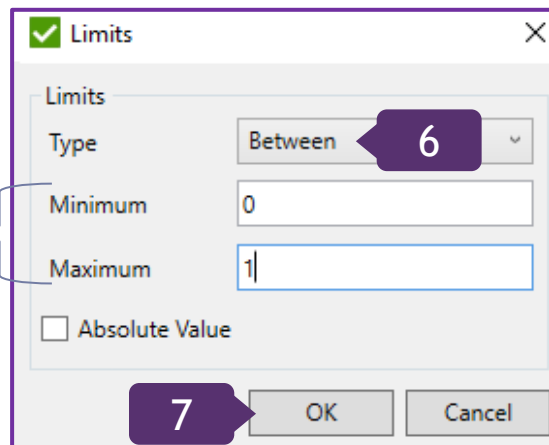
7

Press OK

8

Press OK

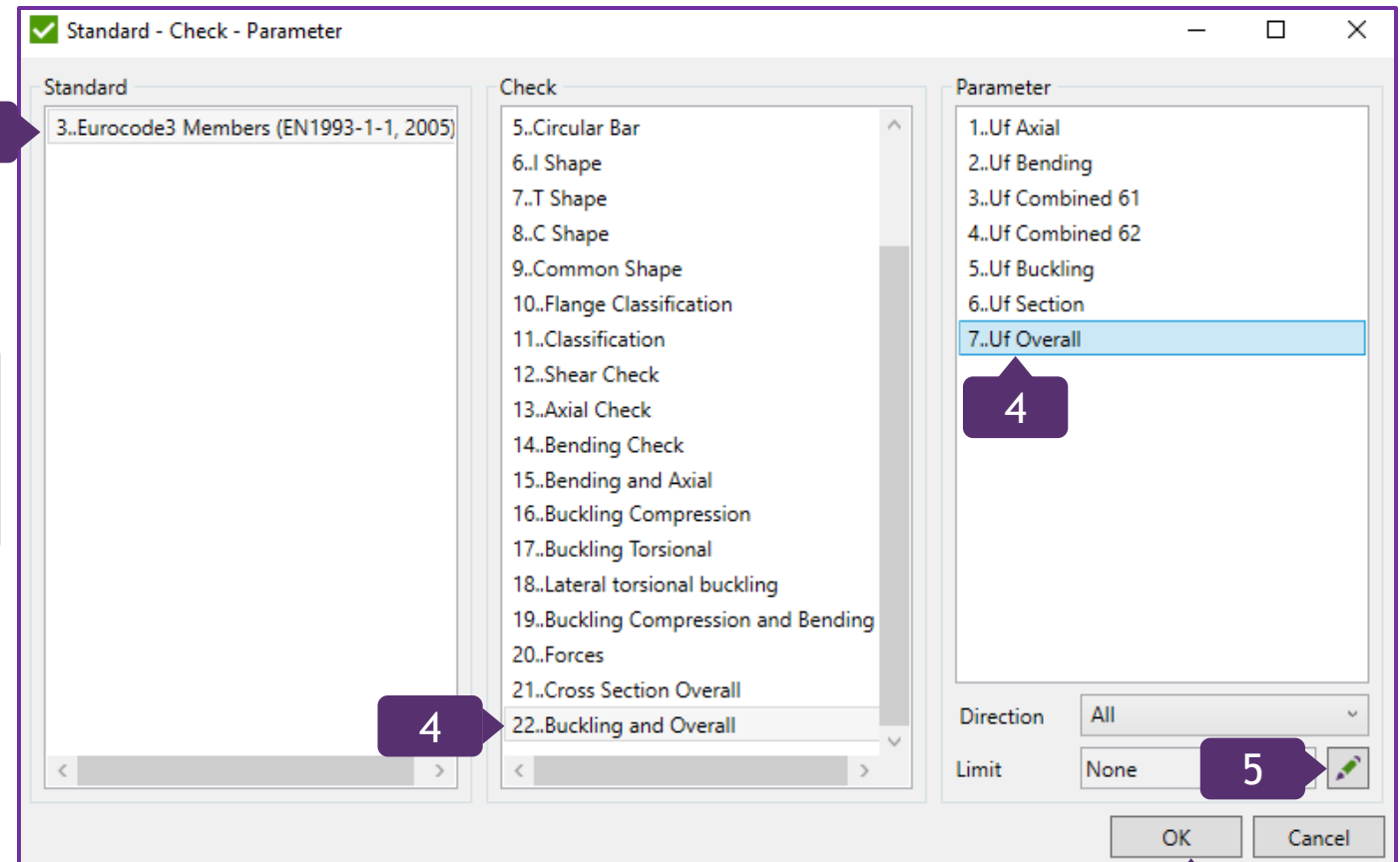
Limits are used to filter results and find the best matching optimal result. A result that passes the limits and matches the variable type (e.g. Min Cross Section Area) will be chosen as an optimal result.



The Limits dialog box is shown with the following details:

- Title bar: Limits
- Limits section: Type is set to *Between* (indicated by callout 6).
- Minimum: 0
- Maximum: 1
- Absolute Value: unchecked
- Buttons: OK (indicated by callout 7) and Cancel

Note: Only checks that fit the type of the rule (beam, plate buckling etc.) will be displayed in the list.



The Standard - Check - Parameter dialog box is shown with the following details:

- Title bar: Standard - Check - Parameter
- Standard list: 3..Eurocode3 Members (EN1993-1-1, 2005) (indicated by callout 4)
- Check list: 22..Buckling and Overall (indicated by callout 4)
- Parameter list: 7..Uf Overall (indicated by callout 4)
- Direction: All
- Limit: None (indicated by callout 5 and a pencil icon)
- Buttons: OK (indicated by callout 8) and Cancel

Note: If the parameter had already been added it will not be shown in the list when adding another parameters.

Add Properties from List

1 Optimization Variable: *Shape Cross Section Area*;
Optimize Variable by: *Min Value* is ON

2 Press  to add multiple Grouped Variables

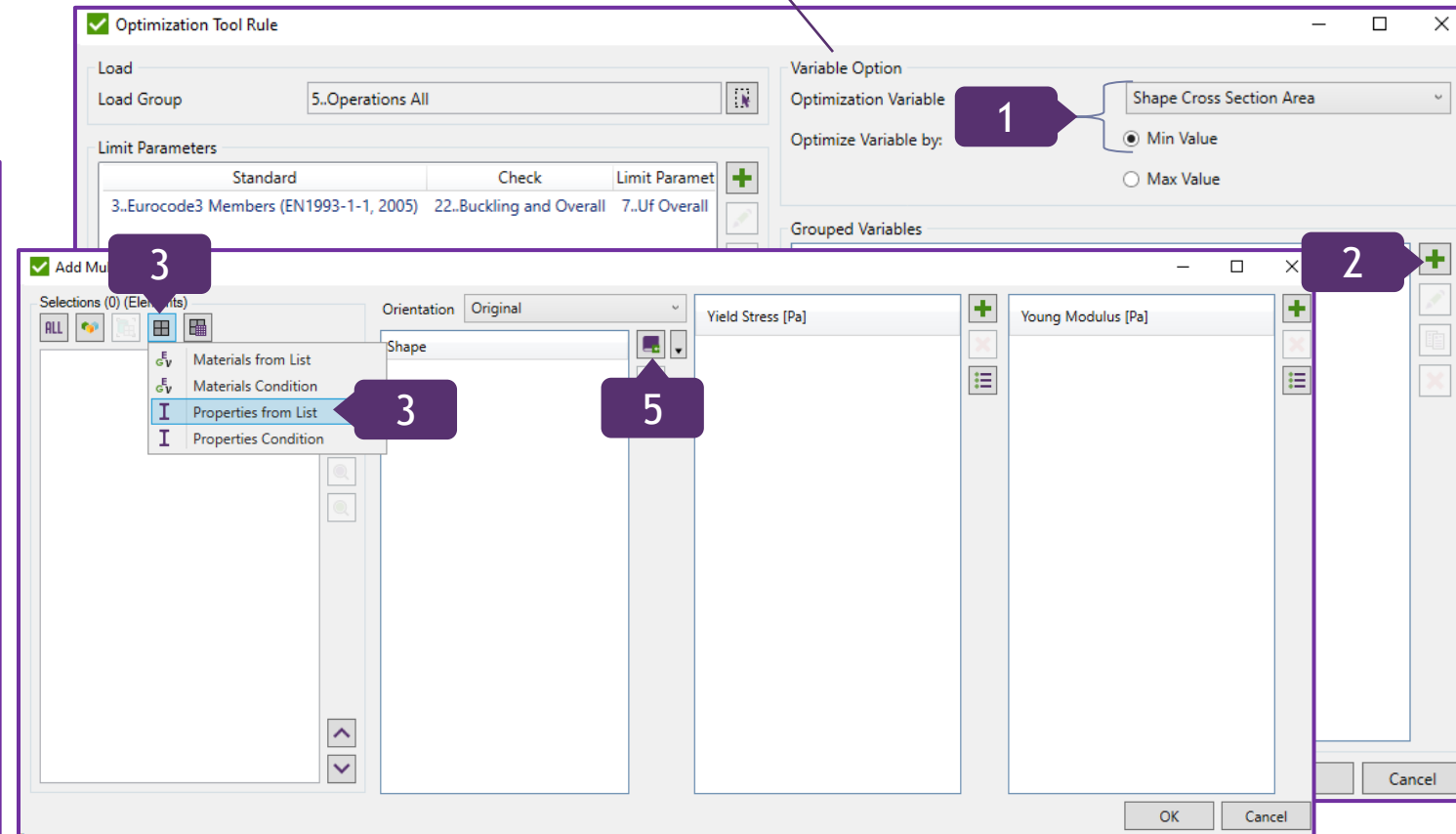
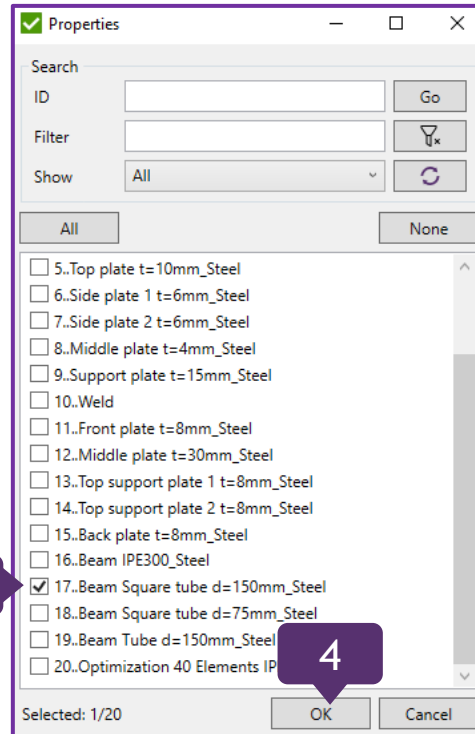
3 Press  and select Properties from List

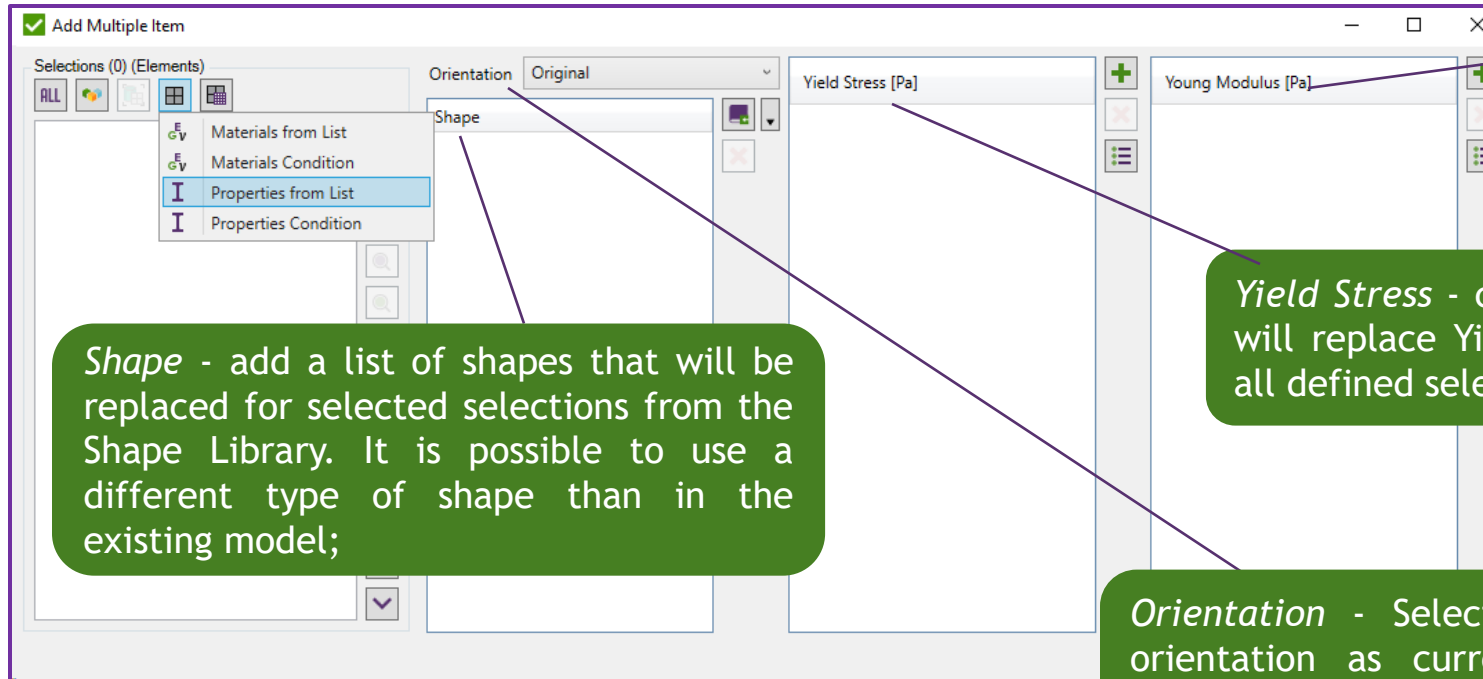
4 Select 17.. *Beam Square tube*
d=150mm_Steel;
Press OK

5 Press  to open
Shape Library

Optimization Variable - select the type of the variable to be optimized
(Shape Cross Section Area, Young Modulus, Yield Stress);

Optimize Variable by - find an optimal result based the on min/max value
of the variable type. For example, to optimize the structure according to
the lowest weight - select Min Value of Shape Cross Section Area.





Shape - add a list of shapes that will be replaced for selected selections from the Shape Library. It is possible to use a different type of shape than in the existing model;

Young Modulus - create a list of variables that will replace Young Modulus of the material in all defined selections;

Yield Stress - create a list of variables that will replace Yield Stress of the material in all defined selections;

Orientation - Select Left, Right, Up, Down or Original (the same orientation as current cross section in the model) cross section orientation that is applied for all selected shapes from the library. For example H cross section can be used as I with modified orientation.

Note: Optimization result will be calculated for all combinations of Selection + Shape + Yield Stress + Young Modulus.

1

Select the cross-sections, as shown on the screen

2

Press *OK*

3

Press *OK*

Shape Library contains a list of predefined or user-defined shapes that can be used in the Optimization. Shapes can be filtered, organized, added or modified.

The Shapes can be filtered by Name in this section.

The screenshot displays the 'Shape Library' window in SDC Verifier. The 'Filter by Name' field is set to 'HSS'. A list of shapes is shown, with 'HSS20X12X.625' selected. The 'Add Multiple Item' dialog is open, showing the selected shape. The 'The result' label points to the 'Add Multiple Item' dialog. The 'The Shapes can be filtered by Name in this section.' label points to the 'Filter by Name' field. The '2' label points to the 'OK' button in the 'Add Multiple Item' dialog. The '3' label points to the 'OK' button in the 'Shape Library' window.

Shape Library Table:

Name	Type	Width, [m]	Height, [m]	Area, [m^2]	I _{yy} , [m^4]	I _{zz} , [m^4]
<input checked="" type="checkbox"/> HSS20X12X.625	Rectangular Tube	0.30	0.51	0.02	8.168e-04	3.669e-04
<input type="checkbox"/> HSS20X12X.500	Rectangular Tube	0.30	0.51	0.02	6.670e-04	3.014e-04
<input type="checkbox"/> HSS20X12X.375	Rectangular Tube	0.30	0.51	0.01	5.107e-04	2.322e-04
<input checked="" type="checkbox"/> HSS20X12X.313	Rectangular Tube	0.30	0.51	0.01	4.301e-04	1.961e-04
<input type="checkbox"/> HSS20X8X.625	Rectangular Tube	0.20	0.51	0.02	6.343e-04	1.463e-04
<input type="checkbox"/> HSS20X8X.500	Rectangular Tube	0.20	0.51	0.02	5.192e-04	1.214e-04
<input checked="" type="checkbox"/> HSS20X8X.375	Rectangular Tube	0.20	0.51	0.01	3.985e-04	9.452e-05
<input type="checkbox"/> HSS20X8X.313	Rectangular Tube	0.20	0.51	0.01	3.360e-04	8.026e-05
<input type="checkbox"/> HSS20X4X.500	Rectangular Tube	0.10	0.51	0.01	3.715e-04	2.526e-05
<input checked="" type="checkbox"/> HSS20X4X.375	Rectangular Tube	0.10	0.51	0.01	2.863e-04	2.029e-05
<input type="checkbox"/> HSS20X4X.313	Rectangular Tube	0.10	0.51	0.01	2.419e-04	1.750e-05
<input type="checkbox"/> HSS20X4X.250	Rectangular Tube	0.10	0.51	0.01	1.963e-04	1.449e-05
<input checked="" type="checkbox"/> HSS18X6X.625	Rectangular Tube	0.15	0.46	0.02	4.126e-04	6.872e-05
<input type="checkbox"/> HSS18X6X.500	Rectangular Tube	0.15	0.46	0.01	3.390e-04	5.770e-05
<input type="checkbox"/> HSS18X6X.375	Rectangular Tube	0.15	0.46	0.01	2.612e-04	4.541e-05
<input checked="" type="checkbox"/> HSS18X6X.313	Rectangular Tube	0.15	0.46	0.01	2.206e-04	3.877e-05
<input type="checkbox"/> HSS18X6X.250	Rectangular Tube	0.15	0.46	0.01	1.790e-04	3.178e-05
<input type="checkbox"/> HSS16X16X.625	Rectangular Tube	0.41	0.41	0.02	5.918e-04	5.918e-04
<input type="checkbox"/> HSS16X16X.500	Rectangular Tube	0.41	0.41	0.02	4.842e-04	4.842e-04
<input type="checkbox"/> HSS16X16X.375	Rectangular Tube	0.41	0.41	0.01	3.715e-04	3.715e-04
<input type="checkbox"/> HSS16X16X.313	Rectangular Tube	0.41	0.41	0.01	3.131e-04	3.131e-04
<input type="checkbox"/> HSS16X12X.625	Rectangular Tube	0.30	0.41	0.02	4.768e-04	3.038e-04
<input type="checkbox"/> HSS16X12X.500	Rectangular Tube	0.30	0.41	0.02	3.907e-04	2.499e-04
<input type="checkbox"/> HSS16X12X.375	Rectangular Tube	0.30	0.41	0.01	3.003e-04	1.928e-04
<input type="checkbox"/> HSS16X12X.313	Rectangular Tube	0.30	0.41	0.01	2.533e-04	1.629e-04
<input type="checkbox"/> HSS16X8X.625	Rectangular Tube	0.20	0.41	0.02	3.618e-04	1.196e-04

Selected Shape HSS20X12X.625 Properties:

Area, [m^2]	0.02	Y Shear Area, [m^2]	0
Moment of Inertia, I _{zz} , [m^4]	3.669e-04	Z Shear Area, [m^2]	0
Moment of Inertia, I _{yy} , [m^4]	8.168e-04	Nonstructural Mass/length, [kg/m]	0
Moment of Inertia, I _{zy} , [m^4]	0	Warping Constant, [m^6]	7.206e-07
Torsional Constant, [m^4]	7.861e-04	Perimeter, [m]	0

Dimensions: Width = 0.3048, Height = 0.508, Thickness = 0.015875

4

Press **OK**

5

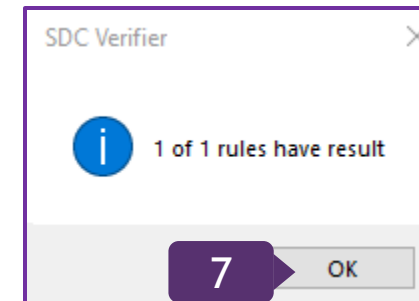
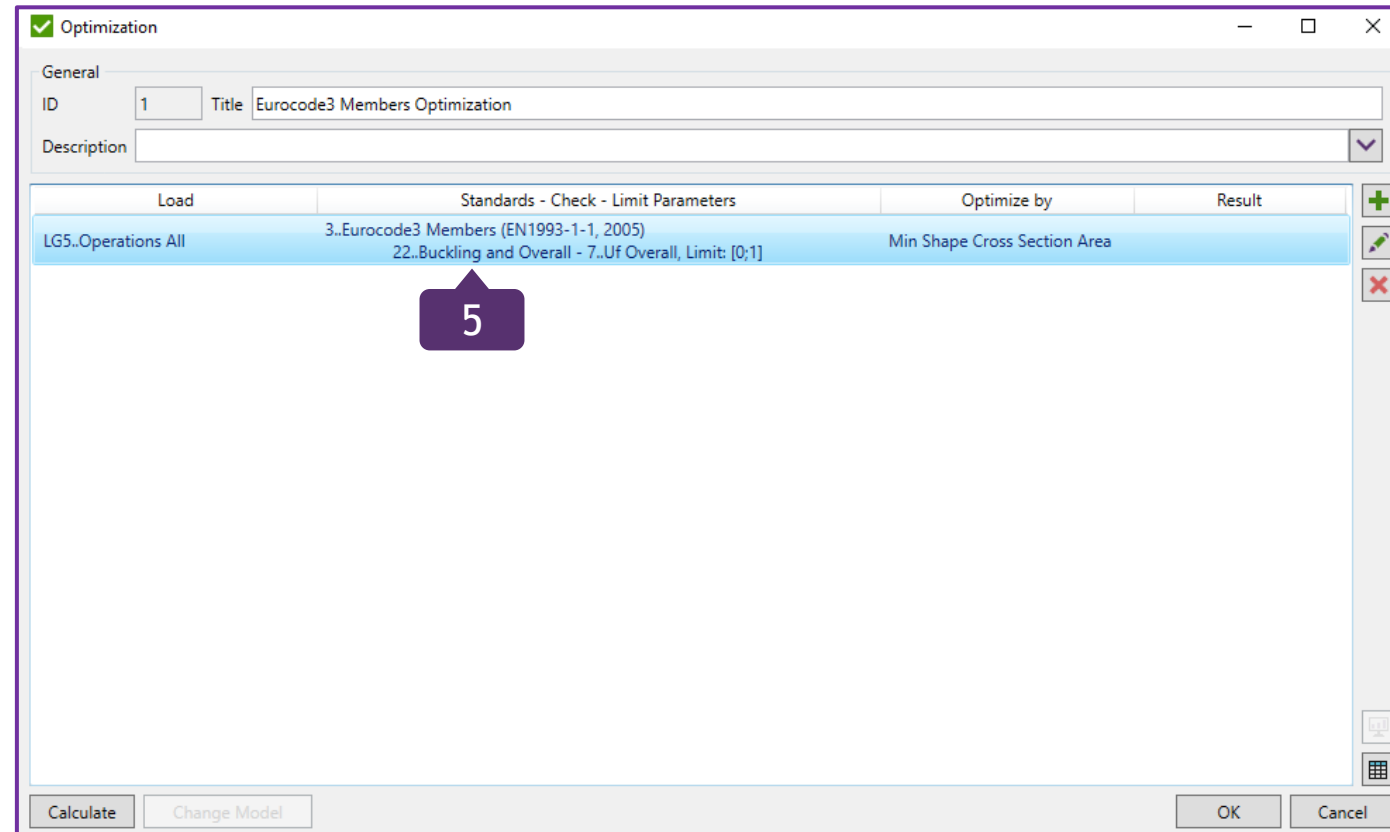
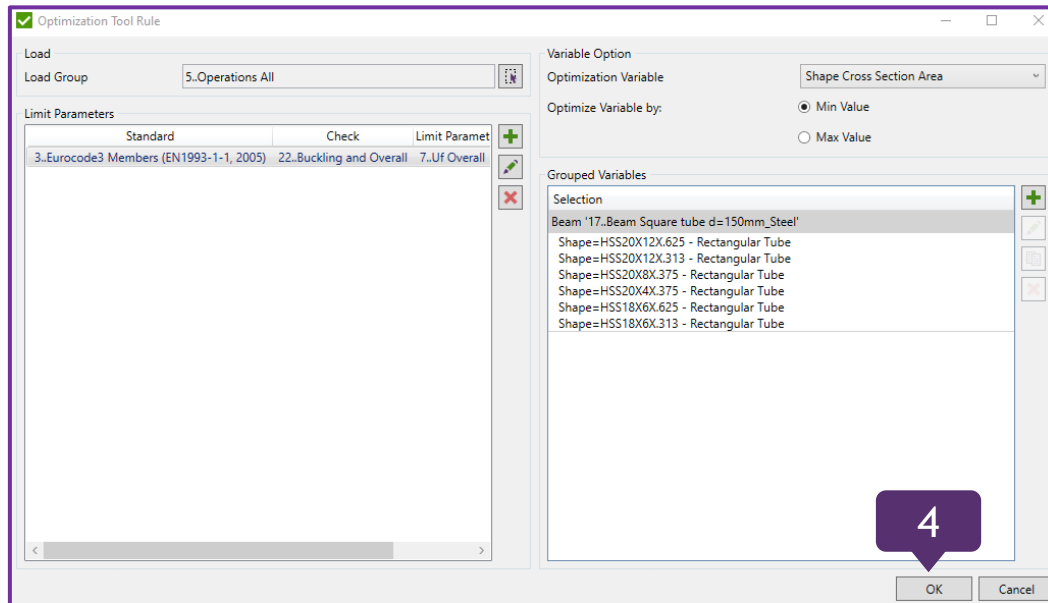
Activate the section

6

Press **Calculate** to run the Optimization

7

Press **OK**



Optimization Results in a Table

1

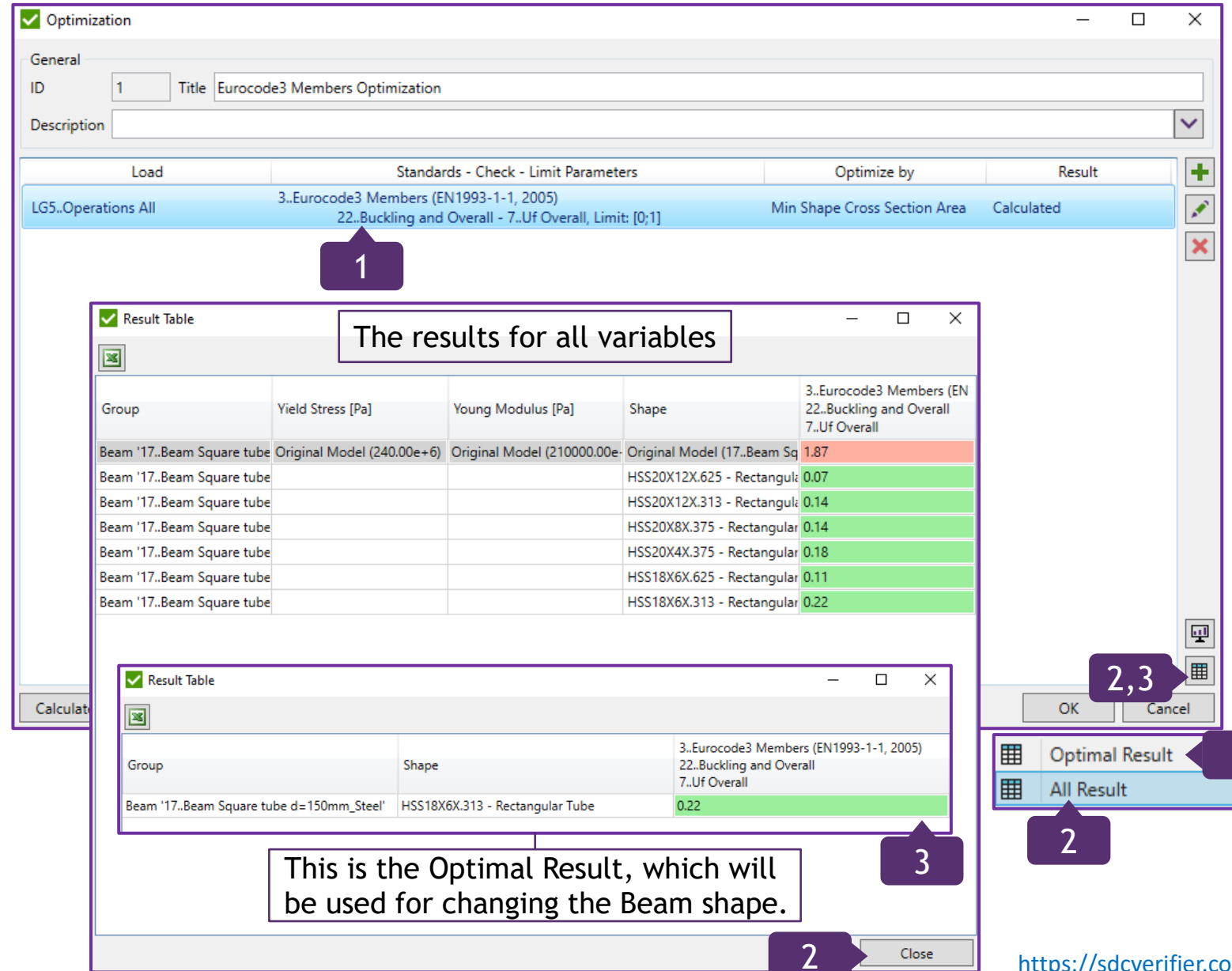
Activate the section

2

Press  and select *All Results*;
Press *Close*

3

Press  and select *Optimal Result*;
Press *Close*



The screenshot shows the 'Optimization' window and two 'Result Table' windows. The 'Optimization' window has a table with columns: Load, Standards - Check - Limit Parameters, Optimize by, and Result. The 'Result Table' windows show the results for all variables and the optimal result.

Optimization Window:

Load	Standards - Check - Limit Parameters	Optimize by	Result
LG5..Operations All	3..Eurocode3 Members (EN1993-1-1, 2005) 22..Buckling and Overall - 7..Uf Overall, Limit: [0;1]	Min Shape Cross Section Area	Calculated

Result Table (All Results):

Group	Yield Stress [Pa]	Young Modulus [Pa]	Shape	3..Eurocode3 Members (EN1993-1-1, 2005) 22..Buckling and Overall 7..Uf Overall
Beam '17..Beam Square tube	Original Model (240.00e+6)	Original Model (210000.00e+6)	Original Model (17..Beam Square tube)	1.87
Beam '17..Beam Square tube			HSS20X12X.625 - Rectangular	0.07
Beam '17..Beam Square tube			HSS20X12X.313 - Rectangular	0.14
Beam '17..Beam Square tube			HSS20X8X.375 - Rectangular	0.14
Beam '17..Beam Square tube			HSS20X4X.375 - Rectangular	0.18
Beam '17..Beam Square tube			HSS18X6X.625 - Rectangular	0.11
Beam '17..Beam Square tube			HSS18X6X.313 - Rectangular	0.22

Result Table (Optimal Result):

Group	Shape	3..Eurocode3 Members (EN1993-1-1, 2005) 22..Buckling and Overall 7..Uf Overall
Beam '17..Beam Square tube d=150mm_Steel'	HSS18X6X.313 - Rectangular Tube	0.22

Callouts:

- 1: Points to the 'Optimization' window.
- 2: Points to the 'Close' button in the 'Result Table' window.
- 2,3: Points to the 'Optimal Result' and 'All Result' buttons in the 'Result Table' window.
- 3: Points to the 'Optimal Result' button in the 'Result Table' window.

Text boxes:

- "The results for all variables" (points to the 'Result Table' window showing all results).
- "This is the Optimal Result, which will be used for changing the Beam shape." (points to the 'Result Table' window showing the optimal result).

Plot Optimization Results

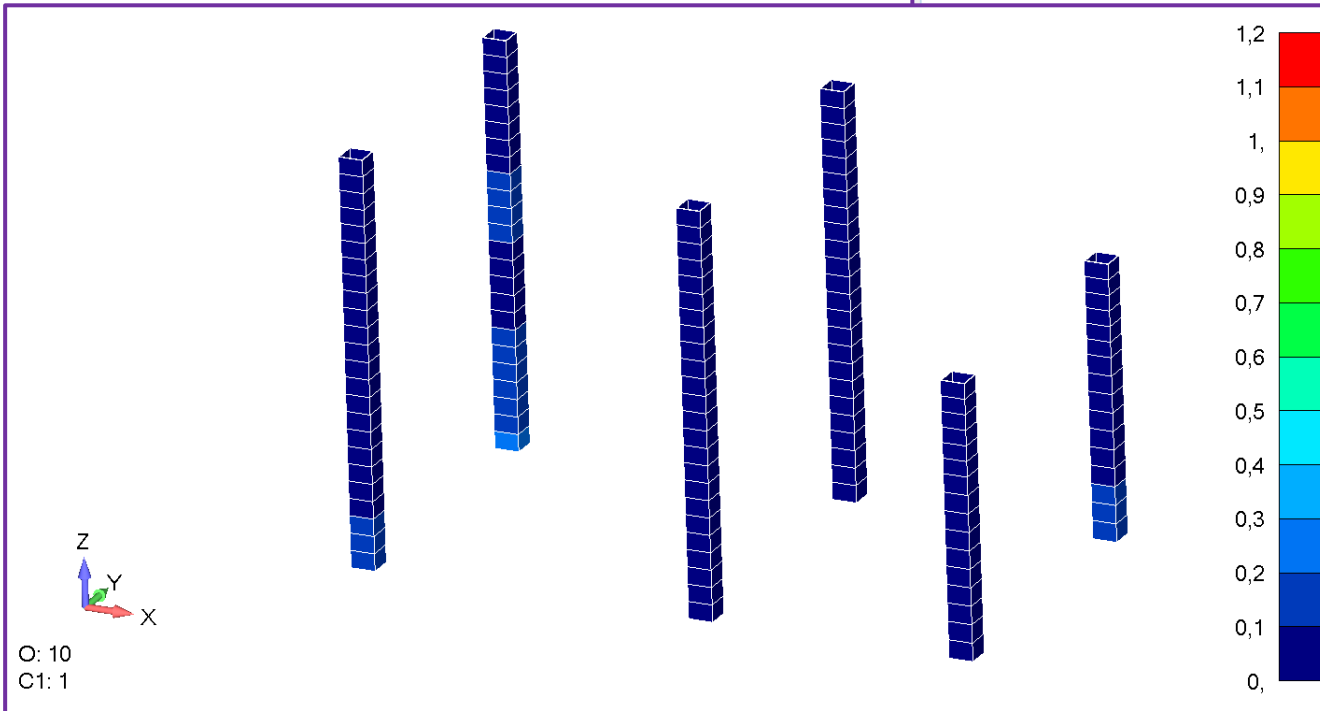
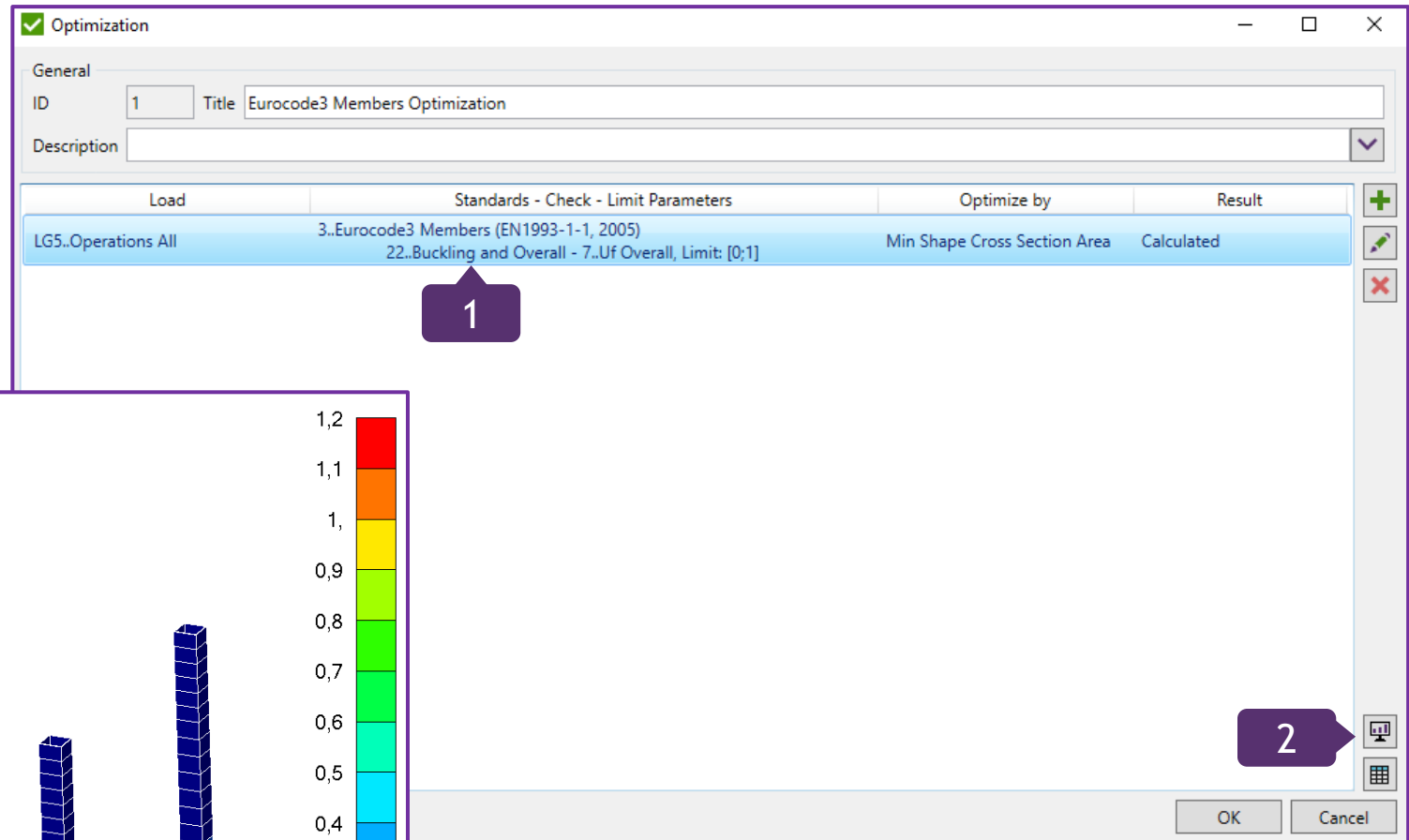
1

Activate the section

2

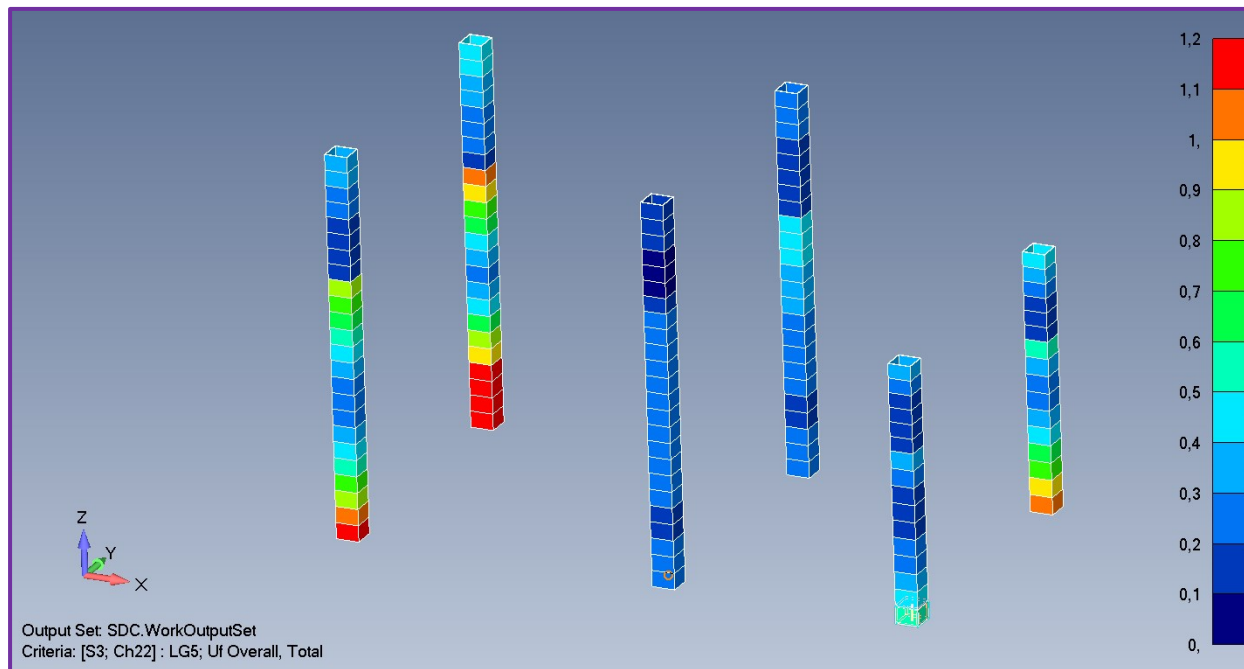
Press  to plot optimal result on the model

The Result

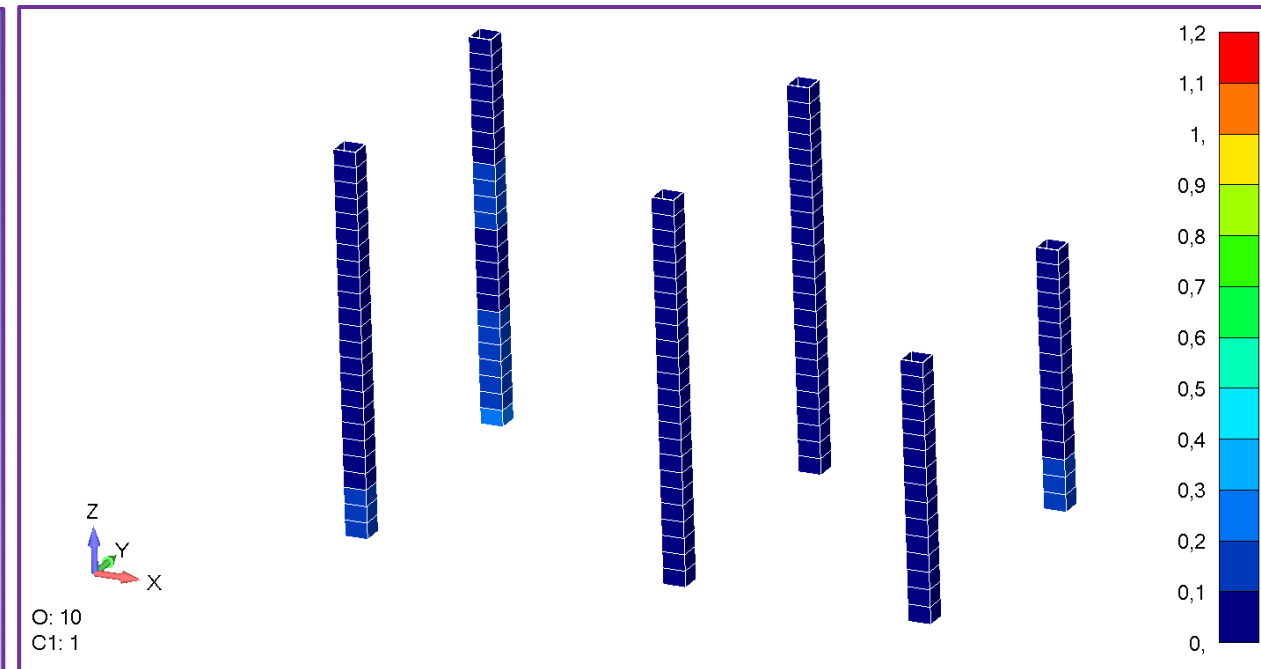


This Tutorial demonstrates only the workflow with the Optimization Tool. Optimization Rule can be set even more precisely. For example, using the Peak Finder you can group only the overshooting elements into a Component and run the Optimization on this Component. Multiple rules with different variables can be set.

The Result before the Optimization



The Result after the Optimization



Add Beam Properties

1 Activate the section

2 Press *Change Model*

3 Press *Yes*

4 Press *OK*

5 Press *OK*

The Result

