SDC VERIFIER

Tutorial

DNV Buckling Strength of Plated Structures (2010) Optimization. Plate Buckling Rule

Updated on: March 26th, 2024

Tested with: SDC Verifier 2023 R2

Femap version 2023.2

Content

- This step-by-step tutorial demonstrates the functionality of SDC Verifier Optimization Tool, incorporating Plate Buckling Rule;

- Model structural members are Optimized based on Criteria Plot results;

- Shape Library Overview;

- Optimization Rules Overview;

- Optimization results in Tables and Plots;

- Results Comparison;

- Automatic Plate Property Change

- Complete information on Optimization Tool may be found on our website via this link: Optimization Tool | Help | SDC for Femap (sdcverifier.com)

Open the Starter Model

1 Launch SDC Verifier for Femap

2 In *File* section, press *Open*

3 Select a project *mudmat_v3.sdcv*

4 Press *Open*
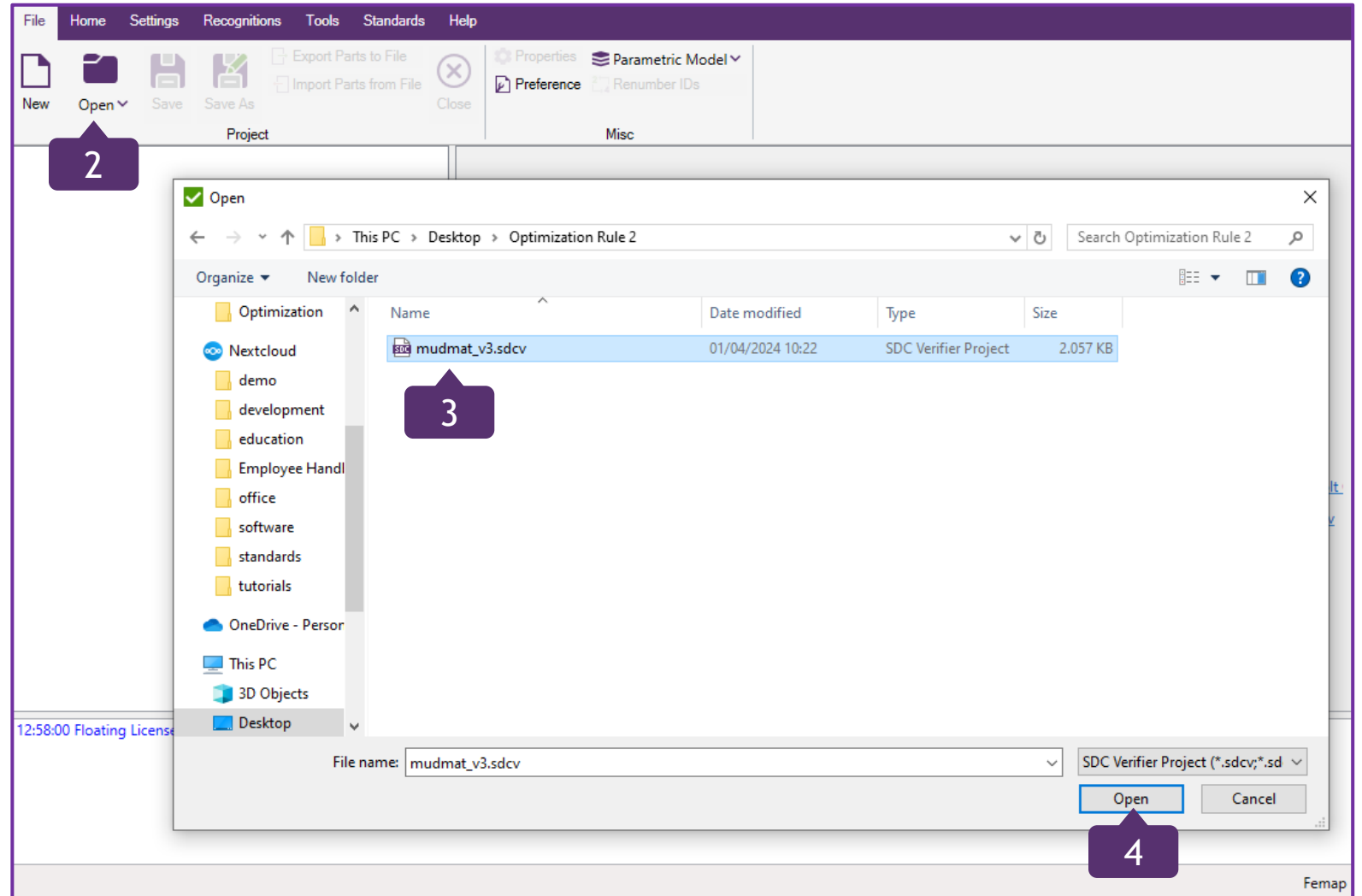
This tutorial uses a Project with predefined Individual Loads, Load Sets and Load Groups.

The model contains Plate, Beam elements and Welds. Also, a relevant Standard has been previously added.

- ▷ ◉ Views (1)
- ▷ ▦ 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
- ◢ S Standards (1)
  - ▷ S 2..DNV Buckling Strength of Plated Structures (2010)
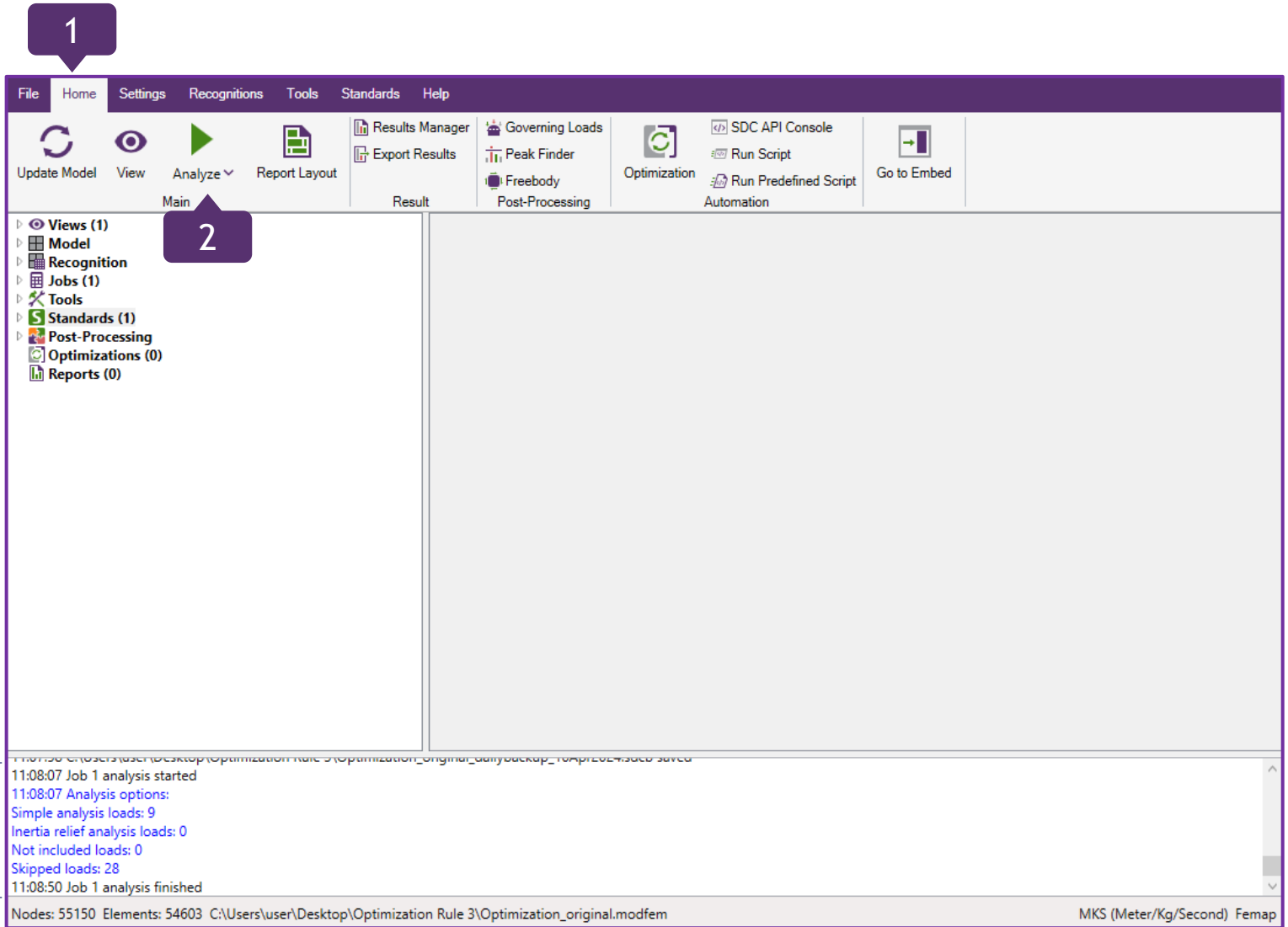- ▷ 🖼 Post-Processing
- 🔃 Optimizations (0)
- 📊 Reports (0)
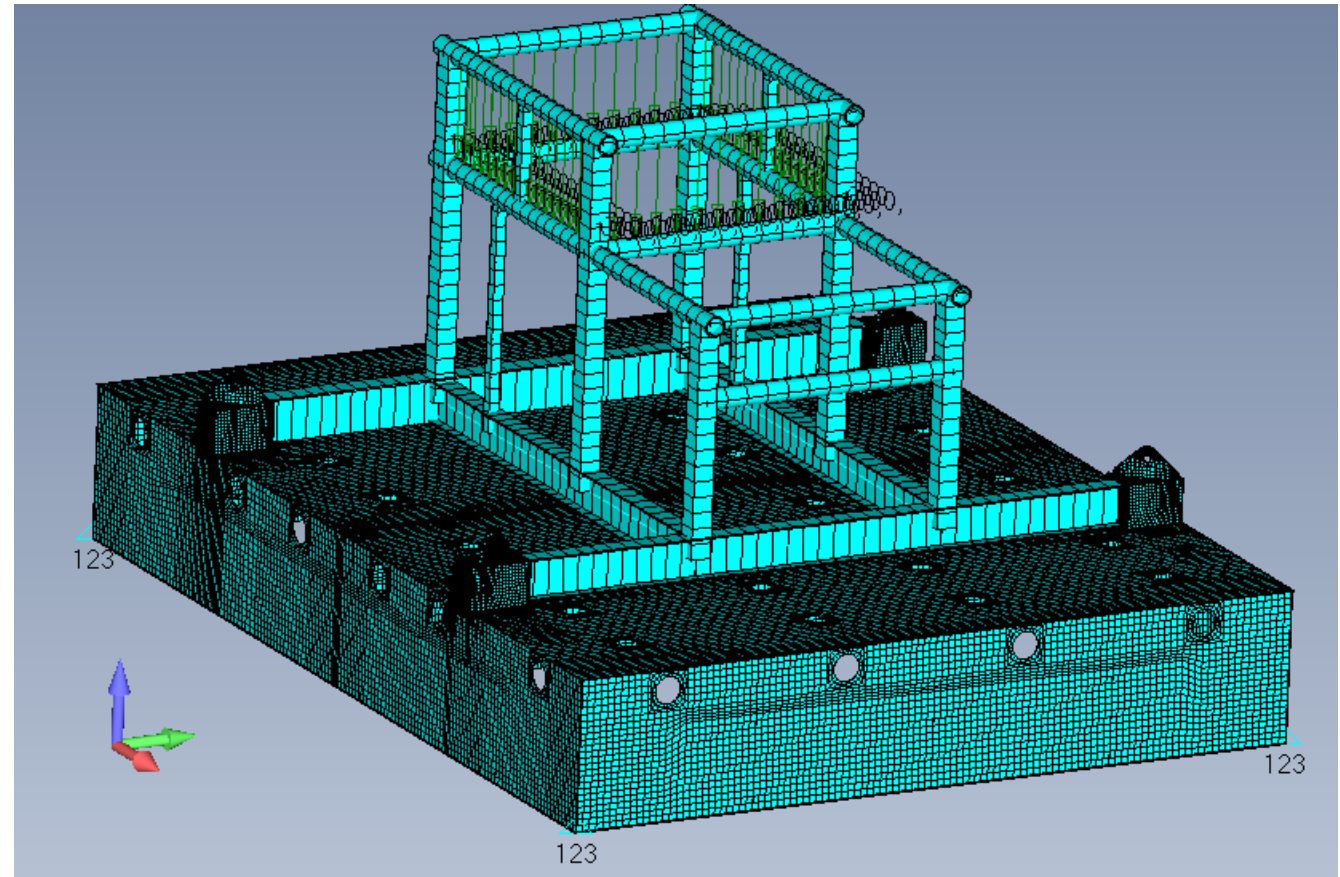
A separate Tutorial with detailed instructions on how to add, define and edit Standard can be found via this link:
https://sdcverifier.com/tutorials/plate-buckling-dnv/

1 Go to *Home* section on the Ribbon

2 Press ▶ on the toolbar to analyze Job

Job 1 analysis started and finished.

```
11:07:50 C:\Users\user\Desktop\Optimization Rule 3\Optimization_original_dailybackup_10Apr2024.sdcb saved
11:08:07 Job 1 analysis started
11:08:07 Analysis options:
Simple analysis loads: 9
Inertia relief analysis loads: 0
Not included loads: 0
Skipped loads: 28
11:08:50 Job 1 analysis finished
```

Nodes: 55150 Elements: 54603 C:\Users\user\Desktop\Optimization Rule 3\Optimization_original.modfem

MKS (Meter/Kg/Second) Femap

DNV Buckling Strength of Plated Structures (2010) Criteria Plot

1 Expand Standards => 2..DNV Buckling Strength of Plated Structures (2010)=> Checks (3) and select *1..Plate Buckling*

2 Execute right click on *1..Plate Buckling* and select *Criteria Plot*

3 Press [icon] to select Load Group

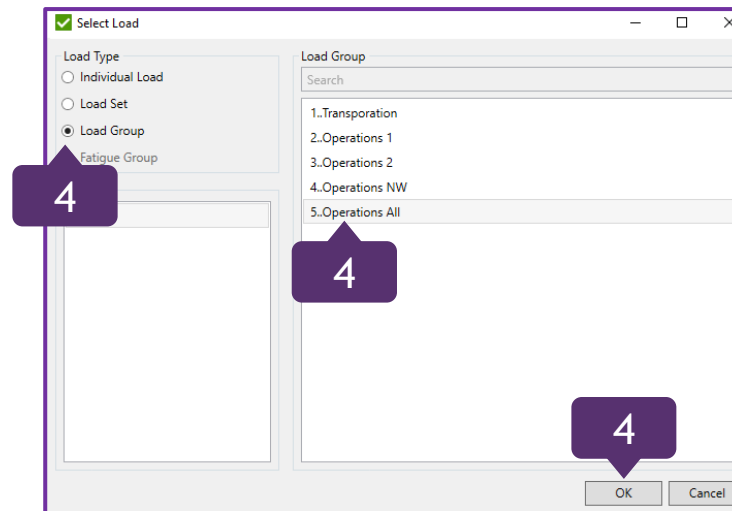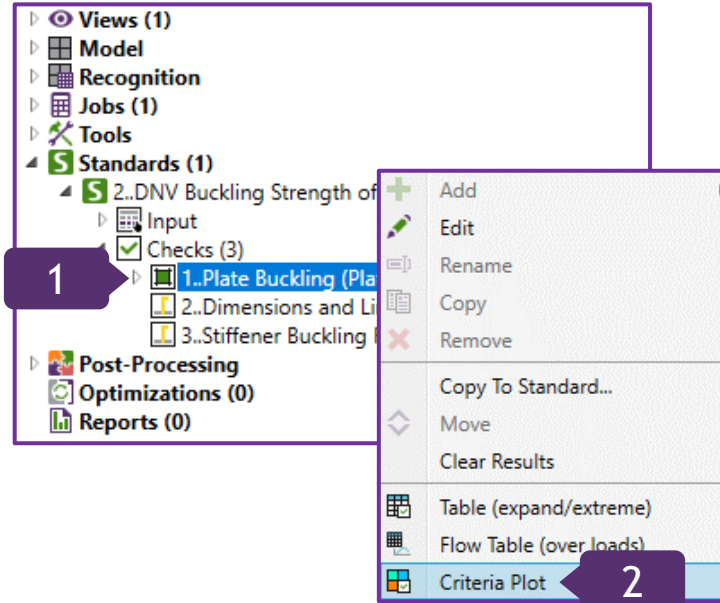**4** In Load Type, select Load Group, and then *5..Operations All*; Press *OK*
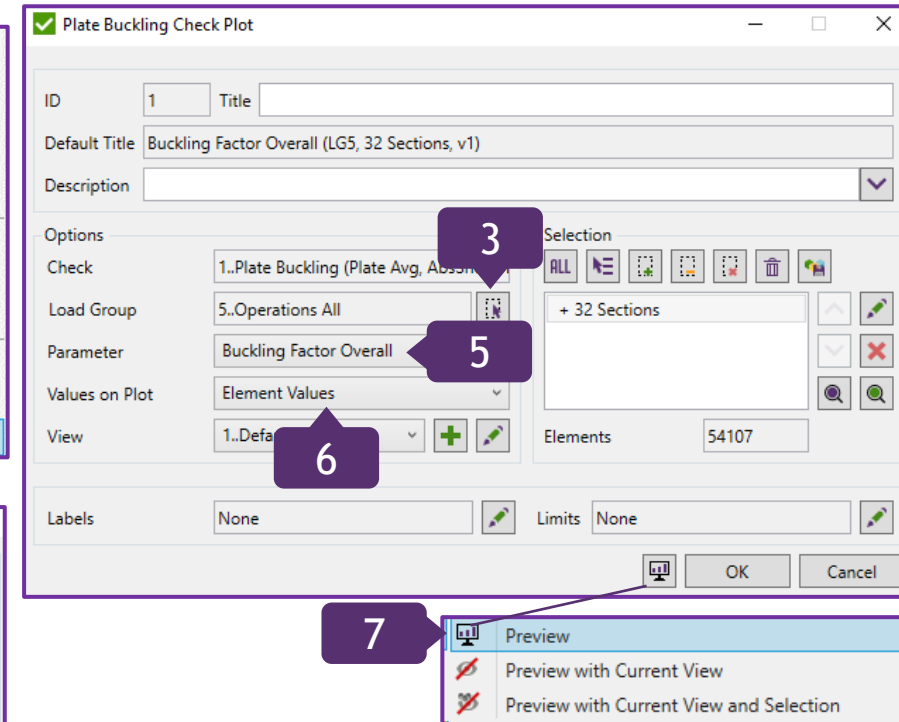
**5** Parameter: *Buckling Factor Overall*

6 Values on Plot: *Element Values*

7 Press [icon] and then *Preview*

The purpose of creating Criteria Plot is to preview the results of DNV Buckling Strength of Plated Structures Check and pick the members for Optimization.

The Plot has been created to see the Buckling Factor Overall on full model.
It is displayed in Femap window.

Output Set: SDC.WorkOutputSet
Criteria: [S2; Ch1] : LG5; Buckling Factor Overall
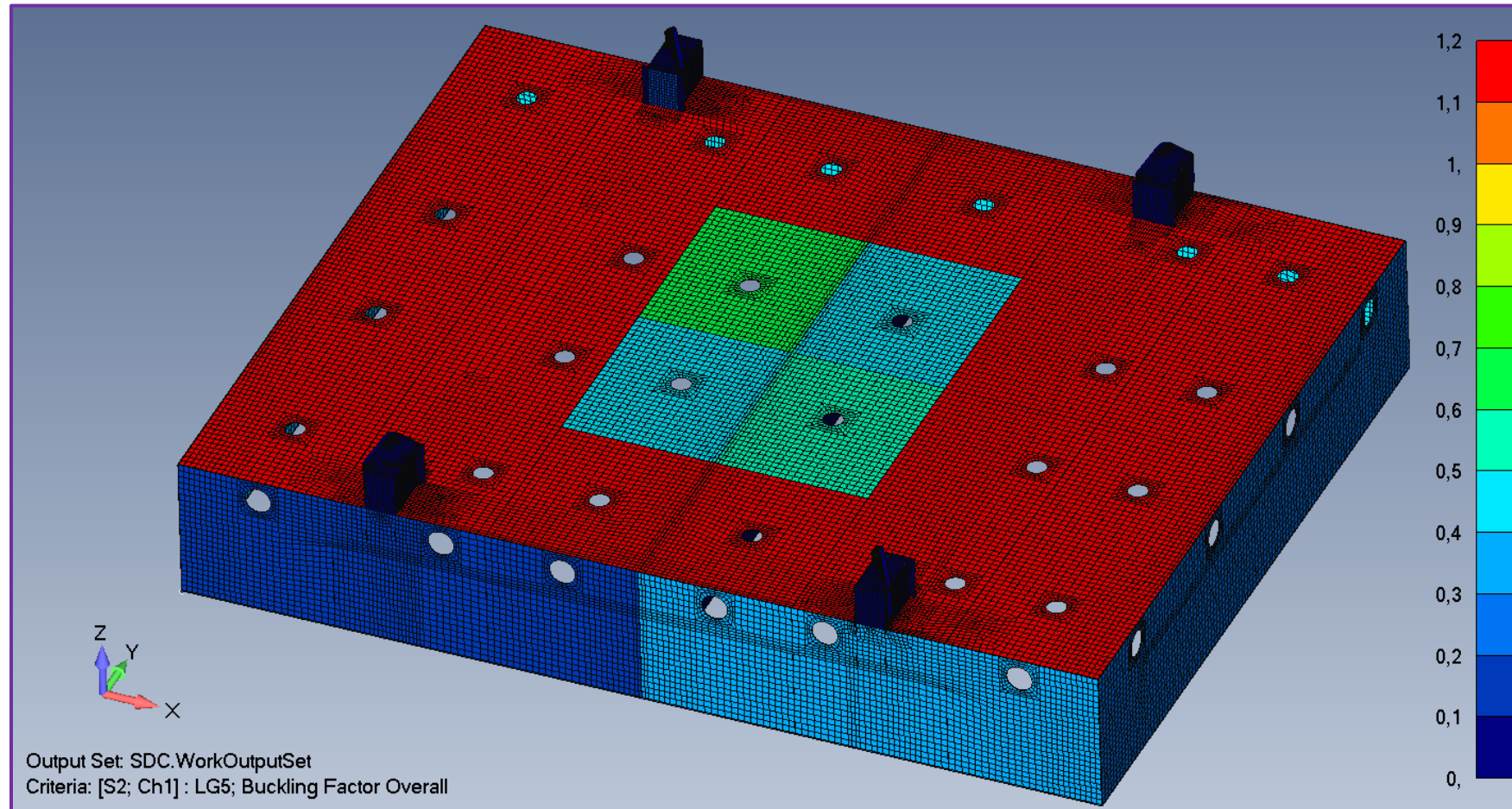
Set Limits for Criteria Plot (Additional Functionality)

1 In Limits, press 🖉

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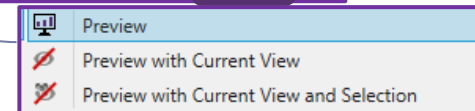Press *OK*

3 Press 🖳 and then *Preview*

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.

The Result

Output Set: SDC.WorkOutputSet
Criteria: [S2; Ch1] : LG5; Buckling Factor Overall
Criteria Limits: Above 1,

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1 Select + *32 Sections* and press ☒ to remove them

2 Press ⯮ to add Condition; Select *Properties*
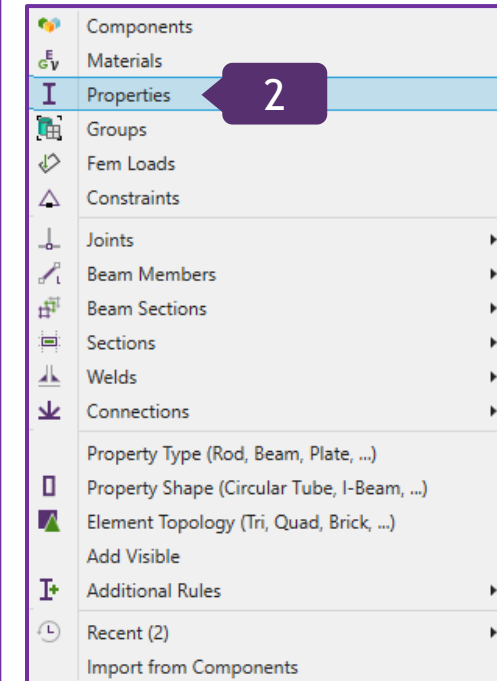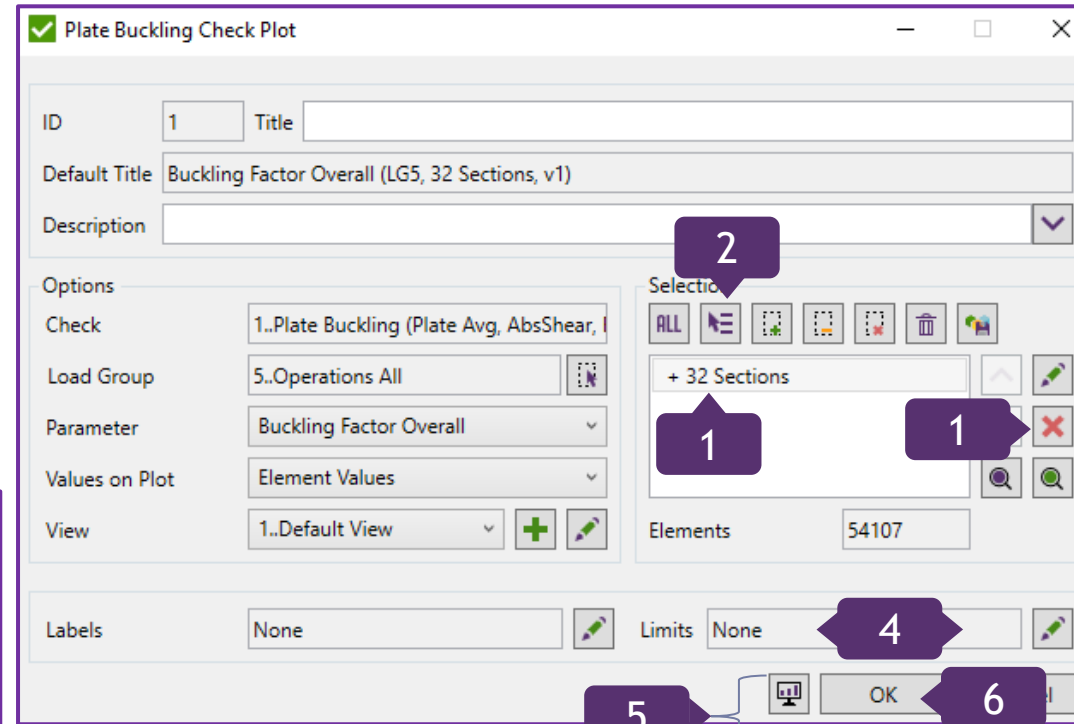
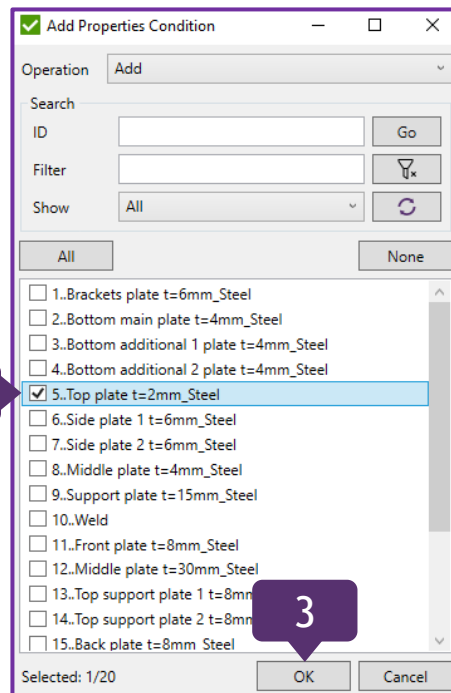**3** Select 5..Top plate t=2mm_Steel; Press *OK*

4 Limits: *None*

5 Press 🖥 and then *Preview*

6 Press *OK*

Plate Buckling Check Plot

ID	1	Title

Default Title: Buckling Factor Overall (LG5, 32 Sections, v1)

Description:

Options

Check	1..Plate Buckling (Plate Avg, AbsShear, ...)	
Load Group	5..Operations All	
Parameter	Buckling Factor Overall	
Values on Plot	Element Values	
View	1..Default View	➕ ✏

Selection

ALL ⯮ ▣ ▢ ▣ 🗑

+ 32 Sections

Elements: 54107

Labels: None

Limits: None

OK

Preview
Preview with Current View
Preview with Current View and Selection

Add Properties Condition

Operation: Add

Search
ID: ___ Go
Filter: ___ ▽
Show: All ↻

All | None

- [ ] 1..Brackets plate t=6mm_Steel
- [ ] 2..Bottom main plate t=4mm_Steel
- [ ] 3..Bottom additional 1 plate t=4mm_Steel
- [ ] 4..Bottom additional 2 plate t=4mm_Steel
- [x] 5..Top plate t=2mm_Steel
- [ ] 6..Side plate 1 t=6mm_Steel
- [ ] 7..Side plate 2 t=6mm_Steel
- [ ] 8..Middle plate t=4mm_Steel
- [ ] 9..Support plate t=15mm_Steel
- [ ] 10..Weld
- [ ] 11..Front plate t=8mm_Steel
- [ ] 12..Middle plate t=30mm_Steel
- [ ] 13..Top support plate 1 t=8mm...
- [ ] 14..Top support plate 2 t=8mm...
- [ ] 15..Back plate t=8mm_Steel

Selected: 1/20 | OK | Cancel

(Right panel)

- 🖳 Components
- ⚙ Materials
- **I Properties** — **2**
- 🏢 Groups
- Fem Loads
- △ Constraints
- Joints
- Beam Members
- Beam Sections
- Sections
- Welds
- Connections
- Property Type (Rod, Beam, Plate, ...)
- Property Shape (Circular Tube, I-Beam, ...)
- Element Topology (Tri, Quad, Brick, ...)
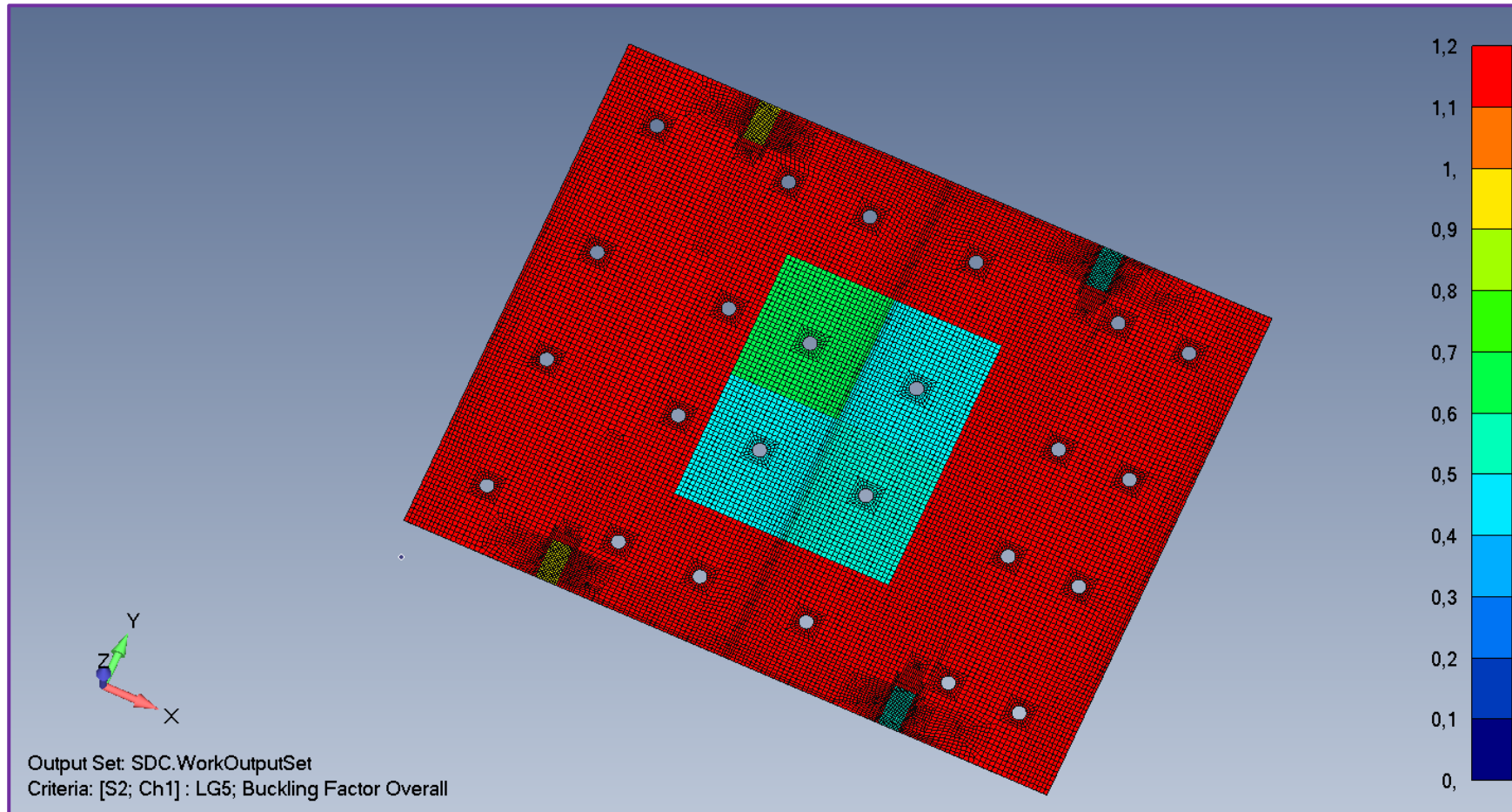- Add Visible
- Additional Rules
- Recent (2)
- Import from Components

The members of 5..Top plate t=2mm_Steel Property have UF Overall value above 1. An Optimization Rule for these members will be created.

9

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

Output Set: SDC.WorkOutputSet
Criteria: [S2; Ch1] : LG5; Buckling Factor Overall

Optimization Tool and Optimization Rule. Theoretical Aspects

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 *Optimizations* and select *Add*

2 Title: *DNV Buckling Strength of Plated Structures (2010)*

3 Press ➕ to create first *Optimization Rule*; Select *Add Plate Buckling Rule*

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

DNV Buckling Strength of Plated Structures (2010) Standard, along with its Checks and Parameters, can be optimized by Plate Buckling Rule.
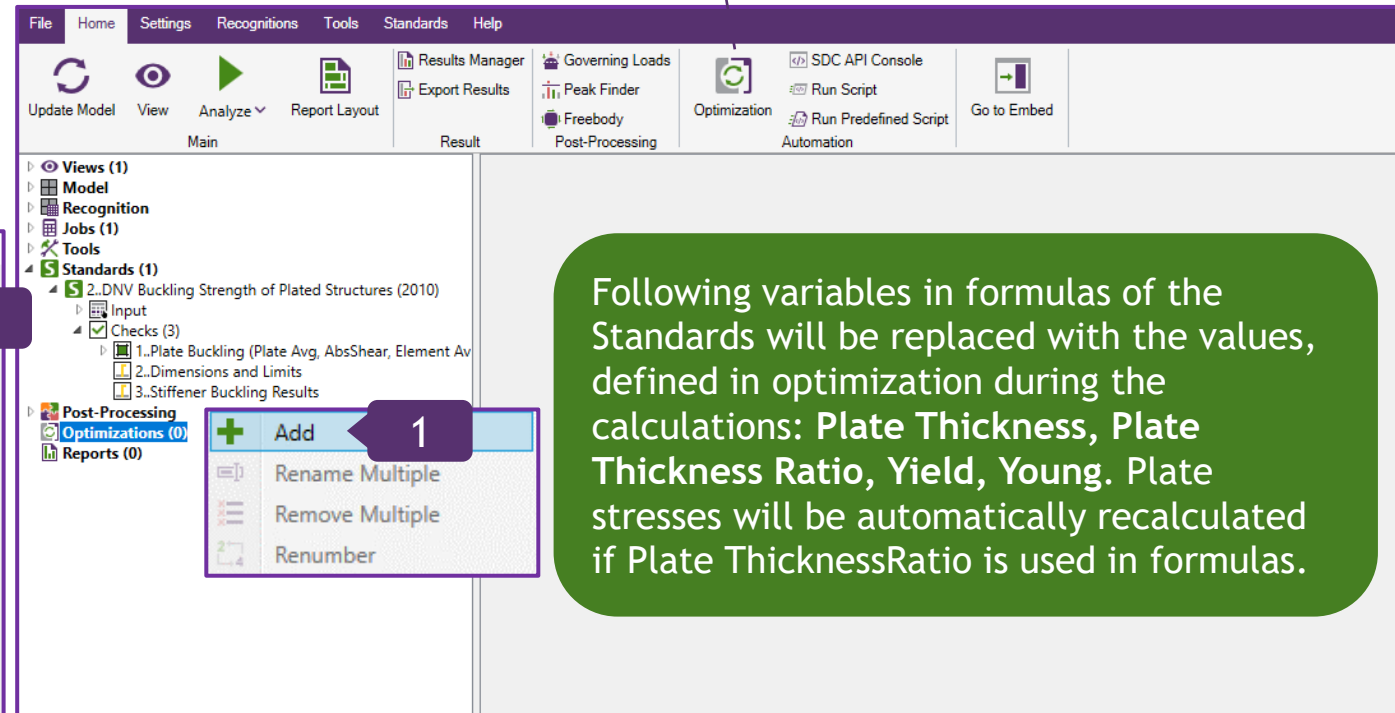
Following variables in formulas of the Standards will be replaced with the values, defined in optimization during the calculations: **Plate Thickness, Plate Thickness Ratio, Yield, Young**. Plate stresses will be automatically recalculated if Plate ThicknessRatio is used in formulas.

Plate Buckling Rule is used to optimize plate thickness, yield stress and/or Young Modulus of buckling plates, recognized by Panel Finder Tool. It is typically used for plate buckling Standards. Common options are described in Optimization Rule.

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

Optimization Tool Rule. DNV Buckling Strength of Plated Structures

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1 In Load, press [⬚] to select *Load Group*

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

3 Press [+] to add *Limit Parameters*

Optimization Tool Rule

Load

Load Group: 5..Operations All — **1**

Limit Parameters

Standard	Check	Limit Parameter	Direction	Limit

3 [+]

Variable Option

Optimization Variable: Plate Thickness

Optimize Variable by:
- ● Min Value
- ○ Max Value

Grouped Variables

Plate Buckling

[+]

Select Load

Load Type
- ○ Individual Load
- ○ Load Set
- ● Load Group — **2**
- ○ Fatigue Group

Jobs

1..Job 1

Load Group

Search

1..Transporation
2..Operations 1
3..Operations 2
4..Operations NW
5..Operations All — **2**

2 OK   Cancel

OK   Cancel

13

4

Standard: *2..DNV Buckling Strength of Plated Structures (2010)*;
Check: *1..Plate Buckling*;
Parameter: *38..Buckling Factor Overall*

5

In Limit, press [pencil icon]
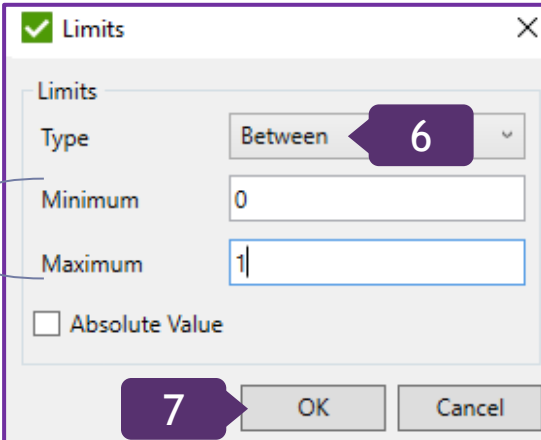
6

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

7

Press *OK*

8

Press *OK*

Note: Only checks that fit the type of the rule (beam, plate buckling etc.) will be displayed in the list.
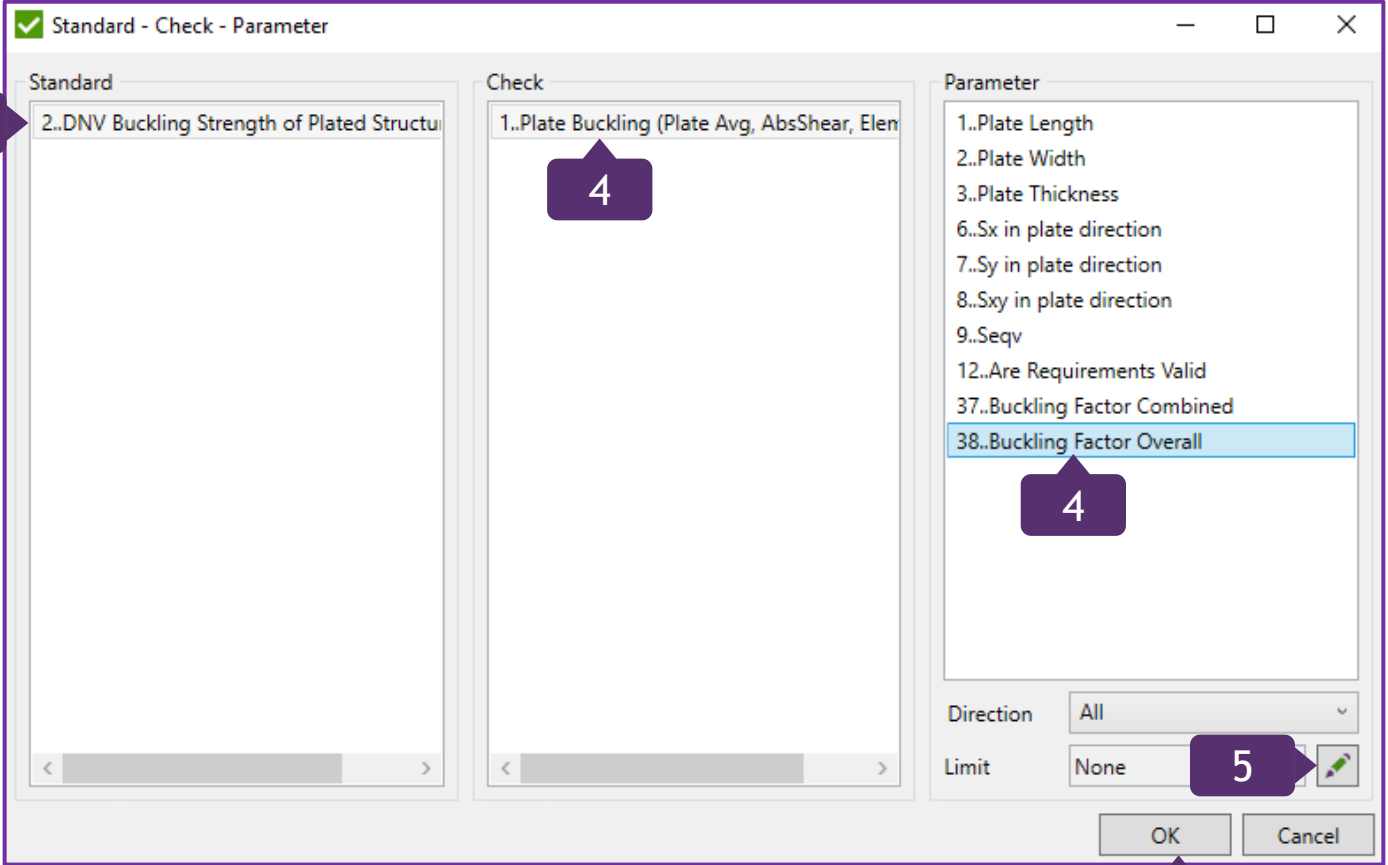
Limits are used to filter results and find the best matching optimal result. A result that passes the limits and matches the variable type (e.g. Min Cross Section Area) will be chosen as an optimal result.

Standard - Check - Parameter

Standard
- 2..DNV Buckling Strength of Plated Structu... **4**

Check
- 1..Plate Buckling (Plate Avg, AbsShear, Elen **4**

Parameter
- 1..Plate Length
- 2..Plate Width
- 3..Plate Thickness
- 6..Sx in plate direction
- 7..Sy in plate direction
- 8..Sxy in plate direction
- 9..Seqv
- 12..Are Requirements Valid
- 37..Buckling Factor Combined
- 38..Buckling Factor Overall **4**

Direction: All
Limit: None **5**

OK   Cancel **8**

Limits

Limits
- Type: Between **6**
- Minimum: 0 **6**
- Maximum: 1

☐ Absolute Value

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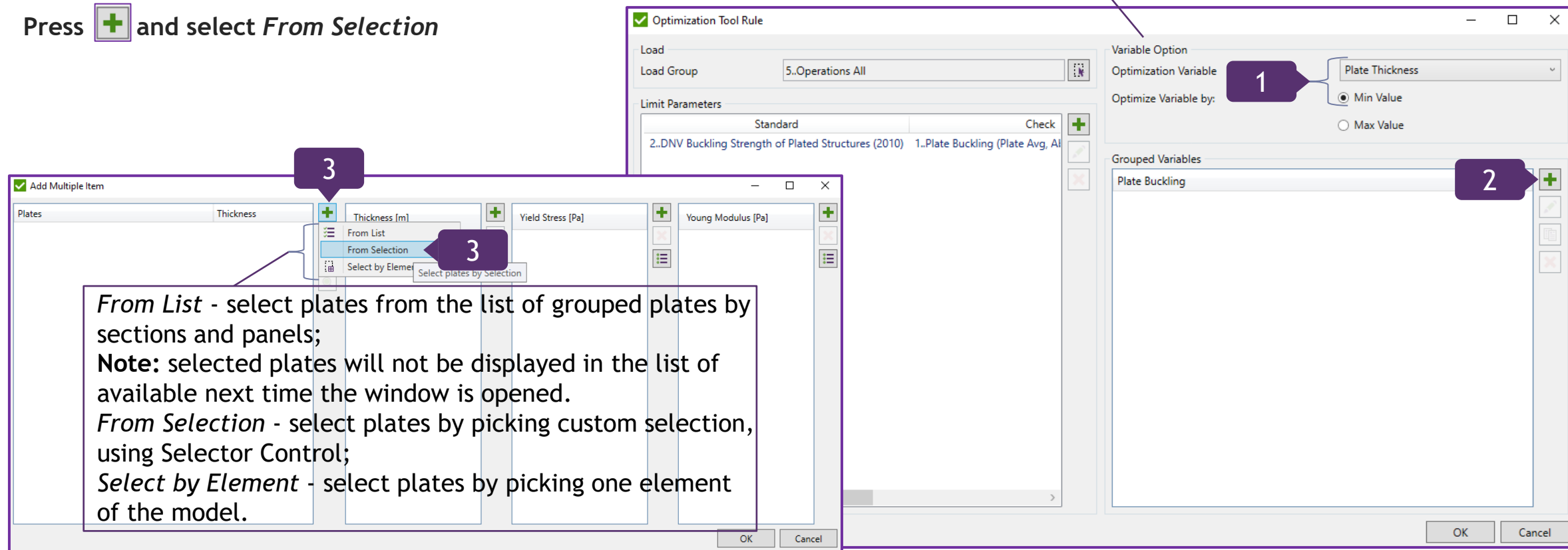
Note: If the parameter had already been added, it will not be shown in the list when adding another parameters.

1 Optimization Variable: Plate Thickness;
Optimize Variable by: *Min Value* is *ON*

2 Press [+] to add multiple Grouped Variables

3 Press [+] and select *From Selection*

> *Optimization Variable* - select the type of the variable to be optimized (Plate Thickness, 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 Plate Thickness.

From List - select plates from the list of grouped plates by sections and panels;
Note: selected plates will not be displayed in the list of available next time the window is opened.
From Selection - select plates by picking custom selection, using Selector Control;
Select by Element - select plates by picking one element of the model.

4 Press [icon] to add Condition

5 Select *Properties*

6 Select 5..Top plate t=2mm_Steel; Press *OK*

7 Press *OK*

8 Press [icon] to define Thickness [m]: 0.004; 0.006; 0.008

9 Press *OK*
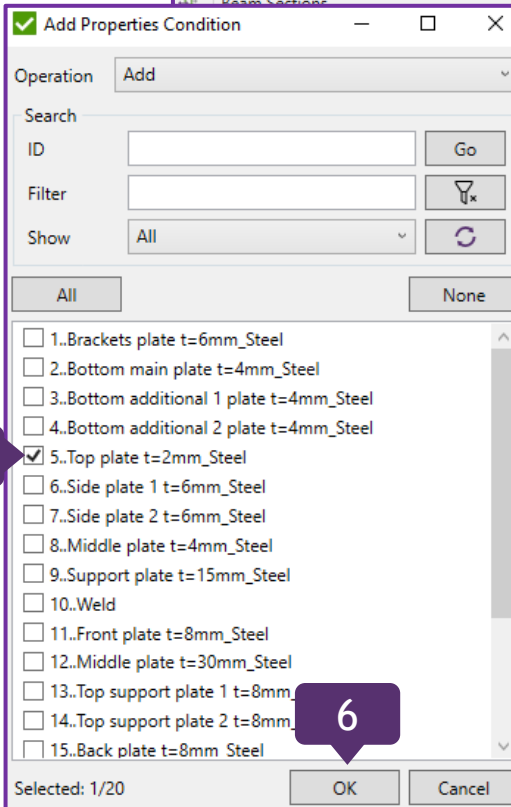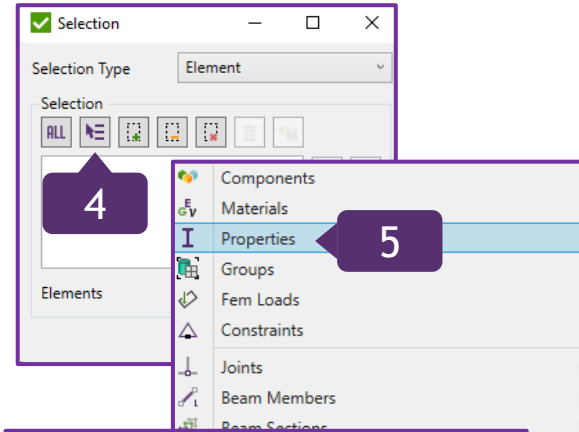
Note: When defining Thickness [m], that refers to Step 8, it is required to press [icon] each time the parameter is incorporated.
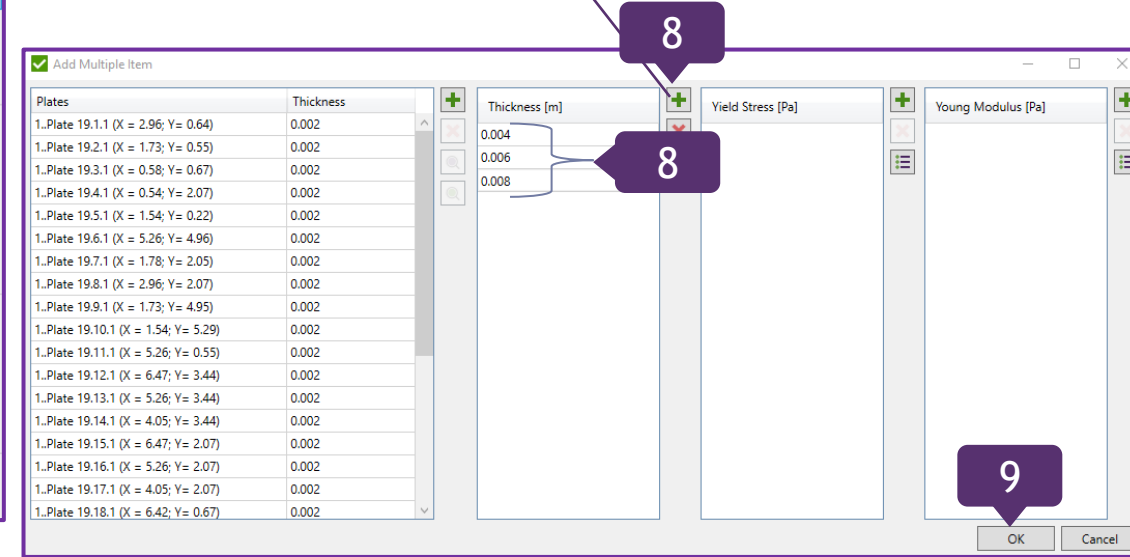
Thickness - create a list of variables that will replace thickness of buckling plate in all defined plates;

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

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

1 Press *OK*

2 Activate the section

3 Press *Calculate* to run *the Optimization*

4 Press *OK*

Grouped Variables that are calculated.

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*

This is the Optimal Result, which will be used for changing the Beam shape.

The results for all variables.

Plot Optimization Results

1   **Activate the section**

2   **Press [icon] to plot optimal result on the model**

3   **Press OK**

The Result

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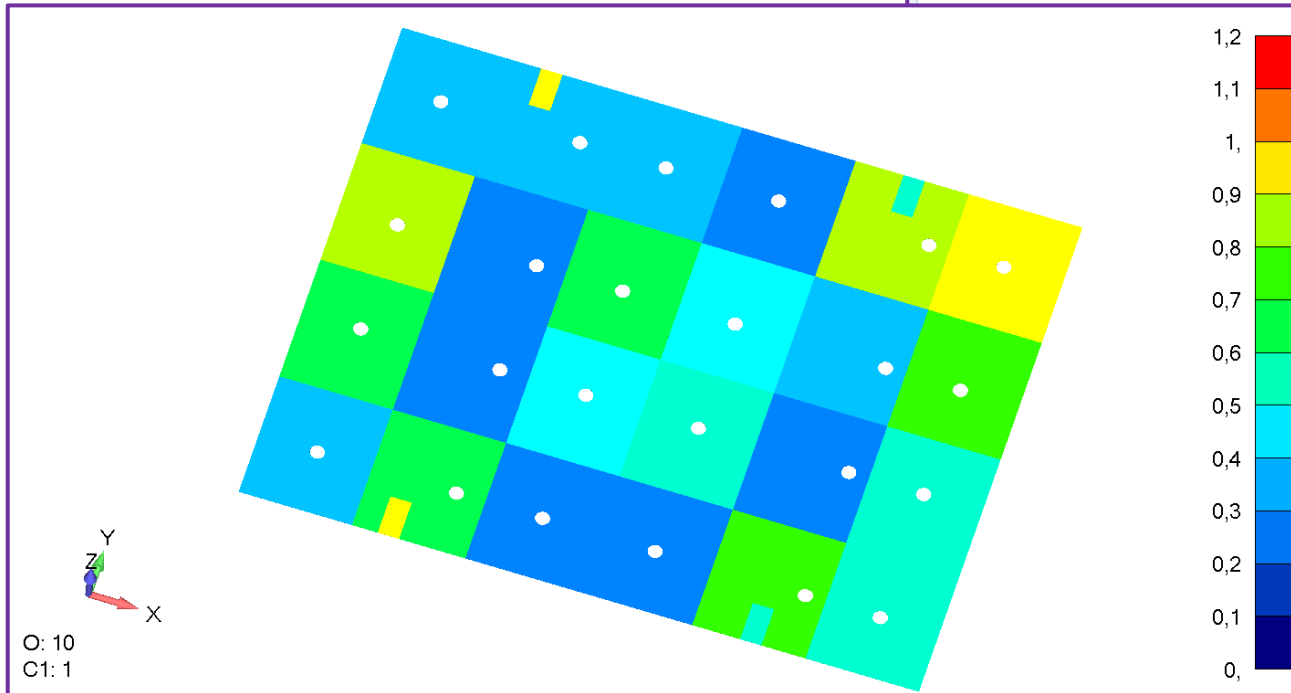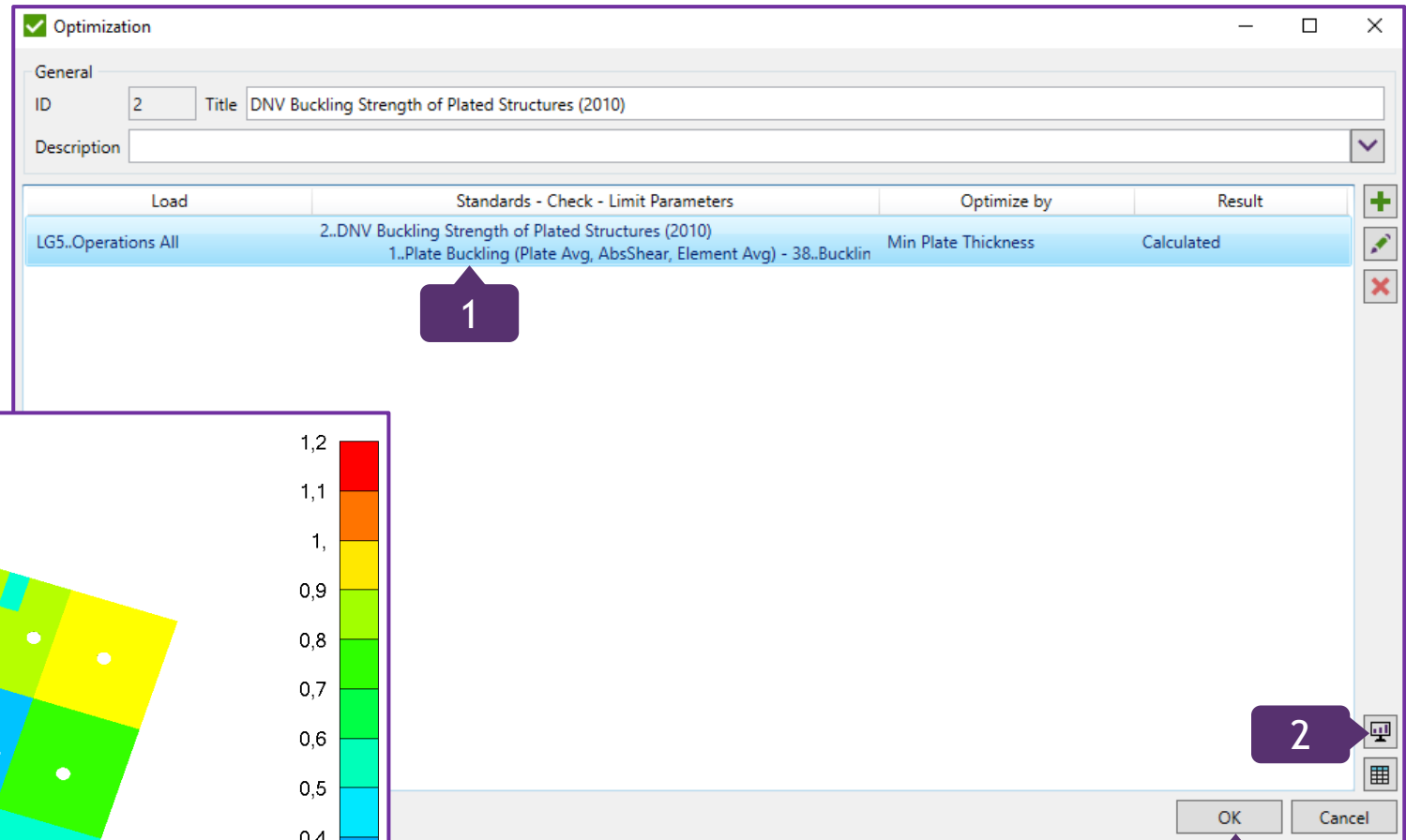
This Tutorial demonstrates only the workflow with the Optimization Tool. Optimization Rule can be set even more precisely. For example, using the Peak Finder you can group only the overshooting elements into a Component and run the Optimization on this Component. Multiple rules with different variables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

The Result before the Optimization.
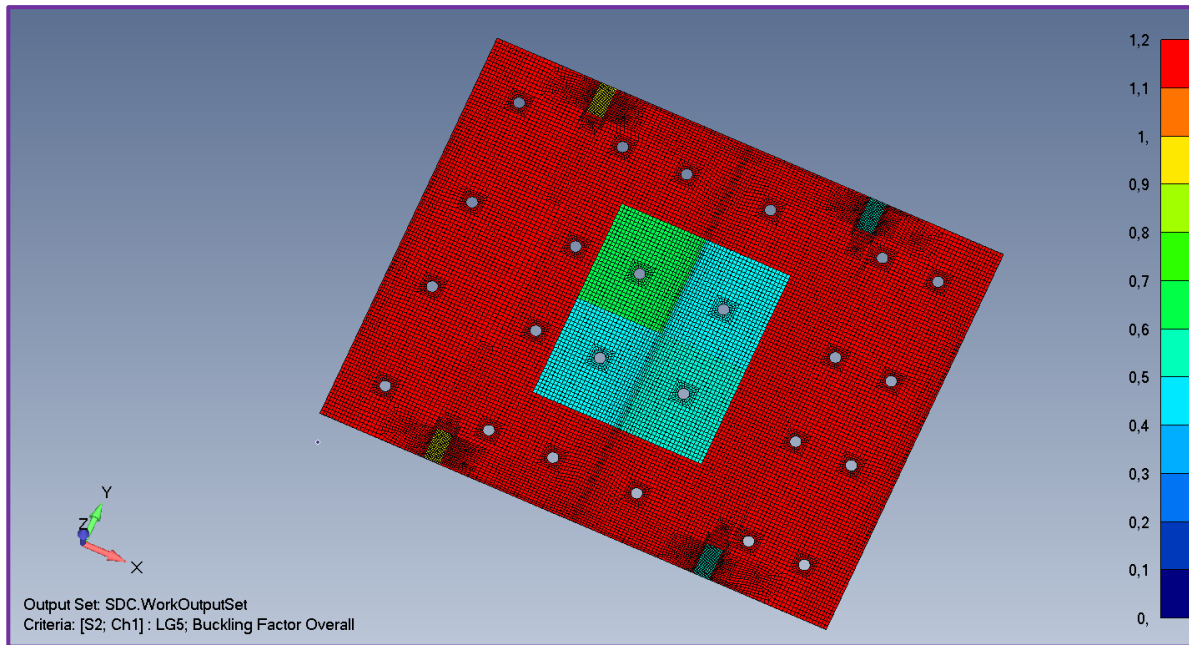
The Result after the Optimization.

Output Set: SDC.WorkOutputSet
Criteria: [S2; Ch1] : LG5; Buckling Factor Overall

O: 10
C1: 1

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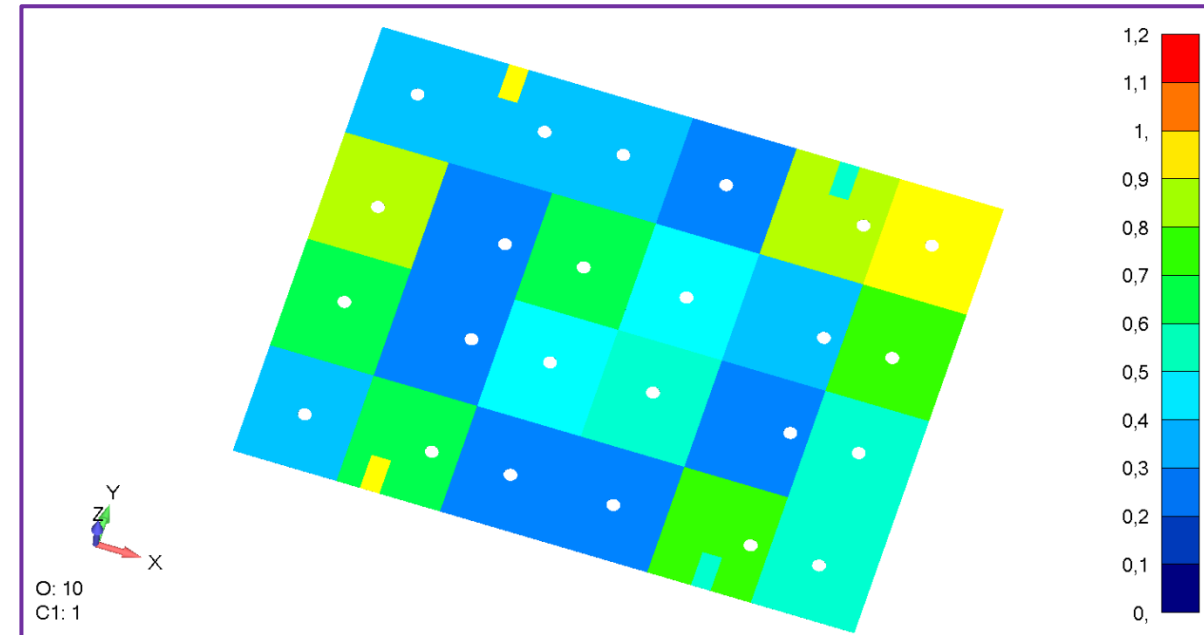
1 Activate the section

2 Press *Change Model*

3 Press *Yes*

4 Press *OK*

5 Press *OK*

The Result

Optimization

General

ID `2` Title `DNV Buckling Strength of Plated Structures (2010)`

Description

Load	Standards - Check - Limit Parameters	Optimize by	Result
LG5..Operations All	2..DNV Buckling Strength of Plated Structures (2010) 1..Plate Buckling (Plate Avg, AbsShear, Element Avg) - 38..Bucklin	Min Plate Thickness	Calculated

1

Model change ✕

⚠ Add plate properties and/or materials to Femap?

[Yes]   [No]

3

Calculate | Change Model

2

OK | Cancel

5

SDC Verifier ✕

ⓘ New plate properties and/or materials were added into Femap model.
Check model in Femap

4 OK