



Tutorial

F.E.M. 1.001 and Eurocode3 Fatigue

Updated on: 11-04-23

Tested with: SDC Verifier 2023 R1

ANSYS 2022 R1

- ▶ This step-by-step tutorial demonstrates how to implement the fatigue check according F.E.M. 1.001 and Eurocode 3 in SDC Verifier.
- ▶ FEM 1.001 Fatigue and Eurocode 3 detailed review;
- ▶ Implementation in SDC Verifier;
- ▶ Weld Finder Tool overview;
- ▶ Fatigue tables and plots;
- ▶ Report preparation and results.

Allowable Stress Design method

The following formulae give for all values of κ the permissible stresses for fatigue

a) $\kappa \leq 0$

- for tension : $\sigma_t = 5 \cdot \sigma_w / (3 - 2 \cdot \kappa)$ (1)

- for compression : $\sigma_c = 2 \cdot \sigma_w / (1 - \kappa)$ (2)

σ_w is given in table above.

b) $\kappa > 0$

- for tension $\sigma_t = \sigma_0 / [1 - \kappa \cdot (1 - \sigma_0 / \sigma_{+1})]$ (3)

- for compression $\sigma_c = 1,2 \cdot \sigma_t$ (4)

where σ_0 = tensile stress for $\kappa = 0$ is given by the formula (1) that is :

$$\sigma_0 = 1,66 \cdot \sigma_w$$

σ_{+1} = tensile stress for $\kappa = +1$ that is the ultimate strength σ_R divided by the coefficient of safety 4/3 :

$$\sigma_{+1} = 0,75 \cdot \sigma_R$$

σ_t is limited in every case to $0,75 \cdot \sigma_R$.

By way of illustration, fig. A.3.6.1. shows curves giving the permissible stress as a function of the ratio κ for the following cases :

- steel A.52 ;
- predominant tensile stress ;
- group E6 ;
- construction cases W_0, W_1, W_2 for unwelded components and cases of construction for joints K_0 to K_4 .

The permissible stresses have been limited to 240 N/mm^2 , i.e. to the permissible stress adopted for checking for ultimate strength.

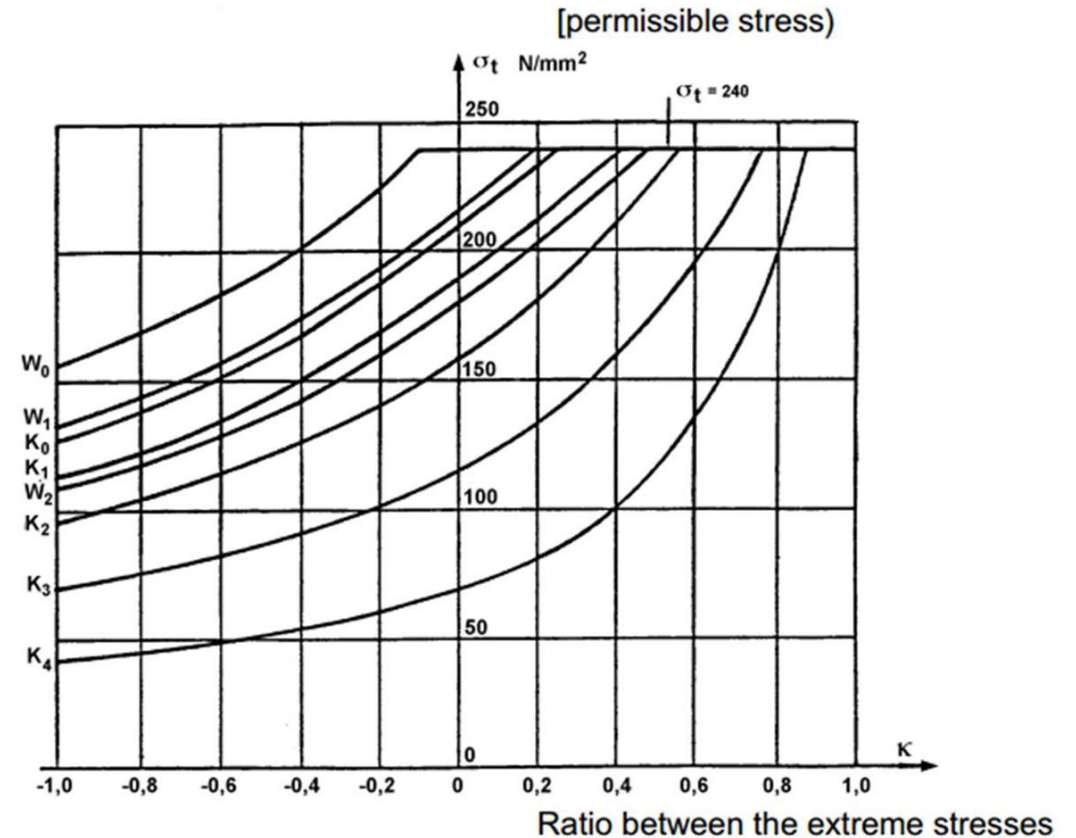


Figure A.3.6.1. - (A 52; tension; group E6)

Kappa Factor

$$\kappa_x = \sigma_{x \min} / \sigma_{x \max}$$

$$\kappa_y = \sigma_{y \min} / \sigma_{y \max}$$

$$\kappa_{xy} = \tau_{xy \min} / \tau_{xy \max}$$

Allowable Stress

a) $\kappa \leq 0$

- for tension : $\sigma_t = 5 \cdot \sigma_w / (3 - 2 \cdot \kappa) \quad (1)$
- for compression : $\sigma_c = 2 \cdot \sigma_w / (1 - \kappa) \quad (2)$

σ_w is given in table above.

b) $\kappa > 0$

- for tension $\sigma_t = \sigma_0 / [1 - \kappa \cdot (1 - \sigma_0 / \sigma_{t1})] \quad (3)$
- for compression $\sigma_c = 1,2 \cdot \sigma_t \quad (4)$

Utilization Factor Combined

$$\left(\frac{\sigma_{x \max}}{\sigma_{xa}} \right)^2 + \left(\frac{\sigma_{y \max}}{\sigma_{ya}} \right)^2 - \frac{\sigma_{x \max} \cdot \sigma_{y \max}}{(\sigma_{xa} \cdot \sigma_{ya})} + \left(\frac{\tau_{xy \max}}{\tau_{xya}} \right)^2 \leq 1$$

where the stress values σ_{xa} , σ_{ya} and τ_{xya} are those resulting from the application of formulae (1), (2), (3) and (4) limited to $0,75 \cdot \sigma_R$.

☒ Add Custom Check

ID

2

Title

Fatigue Check

Alias

Fatigue_Check

Description

☒ Show Parameter Description

Options

☒ Calculate Results over Directions

☒ Calculate Results over Points

Load Calculation

Load Group Only

Selection

All Entities

Parameters (4) / Replacements (0)

Parameter = Kappa (Kappa Factor)

Description: Ratio between the extreme stresses

All: `if(SweldAbs > 0, SweldMin / SweldMax, SweldMax / SweldMin)`

Parameter = Sf (Stress Fatigue)

Description: Permissible stress for fatigue depends on the element group (E1-E8) and weld type

All: `Min(units.FromPaToCurrent(Switch(MaterialType, Fe360, Sf_Fe360(ElementGroup, WeldType), Fe510, Sf_Fe510(ElementGroup, WeldType))), 0.75 * Tensile)`

Parameter = Sallow fatigue (Allowable Stress Fatigue)

Description: Appendix 3.6, formulas (1)-(4)

All: `if(Kappa > 0, if(SweldAbs > 0, 1, 1.2) * (5 / 3 * Sf) / (1 - (1 - (5 / 3 * Sf) / (0.75 * tensile)) * Kappa), if(SweldAbs > 0, (5 * Sf) / (3 - 2 * Kappa), (2 * Sf) / (1 - Kappa)))`

Eqv.: 0

Parameter = Uf (Utilization Factor)

Description: Appendix 3.6, equivalent rule - (5)

All: `Abs(SweldAbs) / Sallow_Fatigue`

XY/YZ/ZX: `Abs(SweldAbs) / (Sallow_Fatigue / if(WeldType <= Weld_K4, SQRT(2), SQRT(3)))`

Eqv.: `pow(me.x, 2) + pow(me.y, 2) + pow(me.z, 2) + pow(me.xy, 2) + pow(me.yz, 2) + pow(me.zx, 2) - sign(SweldAbs.X) * me.x * sign(SweldAbs.Y) * me.y - sign(SweldAbs.Y) * me.y * sign(SweldAbs.Z) * me.z - sign(SweldAbs.Z) * me.z * sign(SweldAbs.X) * me.x`

Overall: `Max(me.x, me.y, me.z, me.xy, me.yz, me.zx, sqrt(me.eqv))`

Stress Fatigue is used in Fatigue Allowable stress calculation

$\kappa \leq 0$

- for tension : $\sigma_t = 5 \cdot \sigma_w / (3 - 2 \cdot \kappa)$ (1)

- for compression : $\sigma_c = 2 \cdot \sigma_w / (1 - \kappa)$ (2)

Stress Fatigue depends on:

- Weld Type (W0-W2, K0-K4);
- Element Group / Loading Group (B1-B6);
- Material Type (St360/St37, St510/St52).

Corresponding values of Stress fatigue in SDC Verifier:

Table T.A.3.6.1.
Values of σ_w depending on the component group and construction case (N/mm²)

Component group	Unwelded components Construction cases						Welded components Construction cases (Steels St 37 to St 52, Fe 360 to Fe 510)				
	W ₀		W ₁		W ₂		K ₀	K ₁	K ₂	K ₃	K ₄
	Fe 360 St 37 St 44	St 52 Fe 510	Fe 360 St 37 St 44	St 52 Fe 510	Fe 360 St 37 St 44	St 52 Fe 510					
E1	249,1	298,0	211,7	253,3	174,4	208,6	(361,9)	(323,1)	(271,4)	193,9	116,3
E2	224,4	261,7	190,7	222,4	157,1	183,2	(293,8)	262,3	220,3	157,4	94,4
E3	202,2	229,8	171,8	195,3	141,5	160,8	238,4	212,9	178,8	127,7	76,6
E4	182,1	201,8	154,8	171,5	127,5	141,2	193,5	172,8	145,1	103,7	62,2
E5	164,1	177,2	139,5	150,6	114,9	124,0	157,1	140,3	117,8	84,2	50,5
E6	147,8	155,6	125,7	132,3	103,5	108,9	127,5	113,8	95,6	68,3	41,0
E7	133,2	136,6	113,2	116,2	93,2	95,7	103,5	92,4	77,6	55,4	33,3
E8	120,0	120,0	102,0	102,0	84,0	84,0	84,0	75,0	63,0	45,0	27,0

Extreme Table

ID: 3 Title:

Description:

Options

Check: 2. Fatigue Check

Load Group: 1..L1-L4

Table Type: Parameter over Directions

Parameter: Stress Fatigue

☒ Detailed (results location) ☐ Short

Selection

+ All welds

Elements: 10916


Fill Table

Extreme	X	Y	Z	XY	YZ	ZX	Eqv	Overall
Minimum								
Value	0.0956e+6	0.0956e+6		0.1275e+6			0.1478e+6	0.0000e+6
Element ID	499	326		326			326	326
Maximum								
Value	0.1138e+6	0.0956e+6		0.1275e+6			0.1478e+6	0.0000e+6
Element ID	326	326		326			326	326
Absolute								
Value	0.1138e+6	0.0956e+6		0.1275e+6			0.1478e+6	0.0000e+6
Element ID	326	326		326			326	326



OK Cancel

Weld Type - also called Notch Case, defines which elements belong to what weld type (K0-K4 - joints affected by welding, W0-W2 - elements and joints, not affected by welding). Weld Type depends on shape, structural design, whole pattern or type and quality of welds.

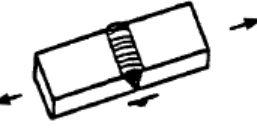
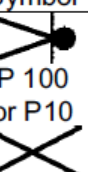
Case W₀

Reference	Description	Figure	Symbol
W ₀	Parent metal, homogeneous surface. Part without joints or breaks in continuity (solid bars) and without notch effects unless the latter can be calculated.		

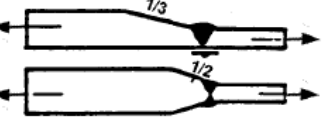

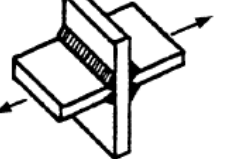
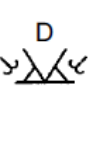
Case K₀ - Slight stress concentration

Reference	Description	Figure	Symbol
0,1	Parts butt-welded (S.Q.) at right angles to direction of forces		




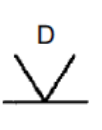
Case K₁ - Moderate stress concentration

Reference	Description	Figure	Symbol
1,1	Parts joined by butt welding (O.Q.) at right angles to the direction of the forces		



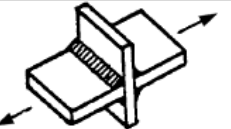
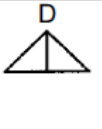
Case K₂ - Medium stress concentration

Reference	Description	Figure	Symbol
2,1	Parts of different thickness butt welded (O.Q.) at right angles to the direction of the forces. Asymmetrical slope : 1 in 3 (or symmetrical slopes : 1 in 2)		
2,4	Cruciform joint made with K-welds (S.Q.) perpendicular to the direction of the forces		

Case K₃ - Severe stress concentration

Reference	Description	Figure	Symbol
3,11	Butt weld with backing strip and no backing run. Backing strip secured by intermittent tack welds		
3,4	Cruciform joint made with K-weld (O.Q.) at right angles to the direction of the forces		

Case K₄ - Very severe stress concentration

Reference	Description	Figure	Symbol
4,1	Parts of different thickness butt welded (O.Q.) at right angles to the direction of the forces. Asymmetrical position without blend slope		
4,4	Cruciform joint made with fillet weld (O.Q.) at right angles to the direction of the forces		

Element Group also called Loading Group depends on: Class of Utilization, Load Spectrum.

Example of Load Cycles:

Load Cycles	Number	Total
Moves per hour	30	
Hours per day	10	300
Days per year	300	90000
Number of Years	20	1800000
Total	Million:	1.8

Class of Utilization B7 ($1.8 \text{ million} < 2 \times 10^6$)

Table T.2.1.4.2. - Classes of utilization

Symbol	Total duration of use (number n of stress cycles)			
B0		n	≤	16 000
B1	16 000	< n	≤	32 000
B2	32 000	< n	≤	63 000
B3	63 000	< n	≤	125 000
B4	125 000	< n	≤	250 000
B5	250 000	< n	≤	500 000
B6	500 000	< n	≤	1 000 000
B7	1 000 000	< n	≤	2 000 000
B8	2 000 000	< n	≤	4 000 000
B9	4 000 000	< n	≤	8 000 000
B10	8 000 000	< n		

Load Spectrum

Table T.2.1.4.3. - Spectrum classes

Symbol	Spectrum factor k_{sp}			
P1		k_{sp}	≤	0,125
P2	0,125	< k_{sp}	≤	0,250
P3	0,250	< k_{sp}	≤	0,500
P4	0,500	< k_{sp}	≤	1,000

$$k_{sp} = (\sigma_1 / \sigma_{max})^c (n_1 / n) + (\sigma_2 / \sigma_{max})^c (n_2 / n) + \dots + (\sigma_r / \sigma_{max})^c (n_r / n) = \sum_{i=1}^r [(\sigma_i / \sigma_{max})^c (n_i / n)]$$

$$n_1 + n_2 + \dots + n_r = \sum_{i=1}^r n_i = n$$


Element Group

Table T.2.1.4.4. - Component groups

Stress Spectrum class	Class of utilization										
	B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
P1	E1	E1	E1	E1	E2	E3	E4	E5	E6	E7	E8
P2	E1	E1	E1	E2	E3	E4	E5	E6	E7	E8	E8
P3	E1	E1	E2	E3	E4	E5	E6	E7	E8	E8	E8
P4	E1	E2	E2	E4	E5	E6	E7	E8	E8	E8	E8

Open the starter model

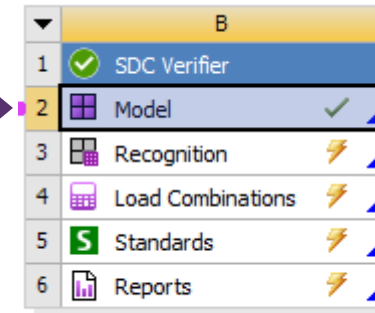
1

Open in ANSYS Workbench 
FEM. 1.001 and Eurocode 3 Fatigue.wbpz

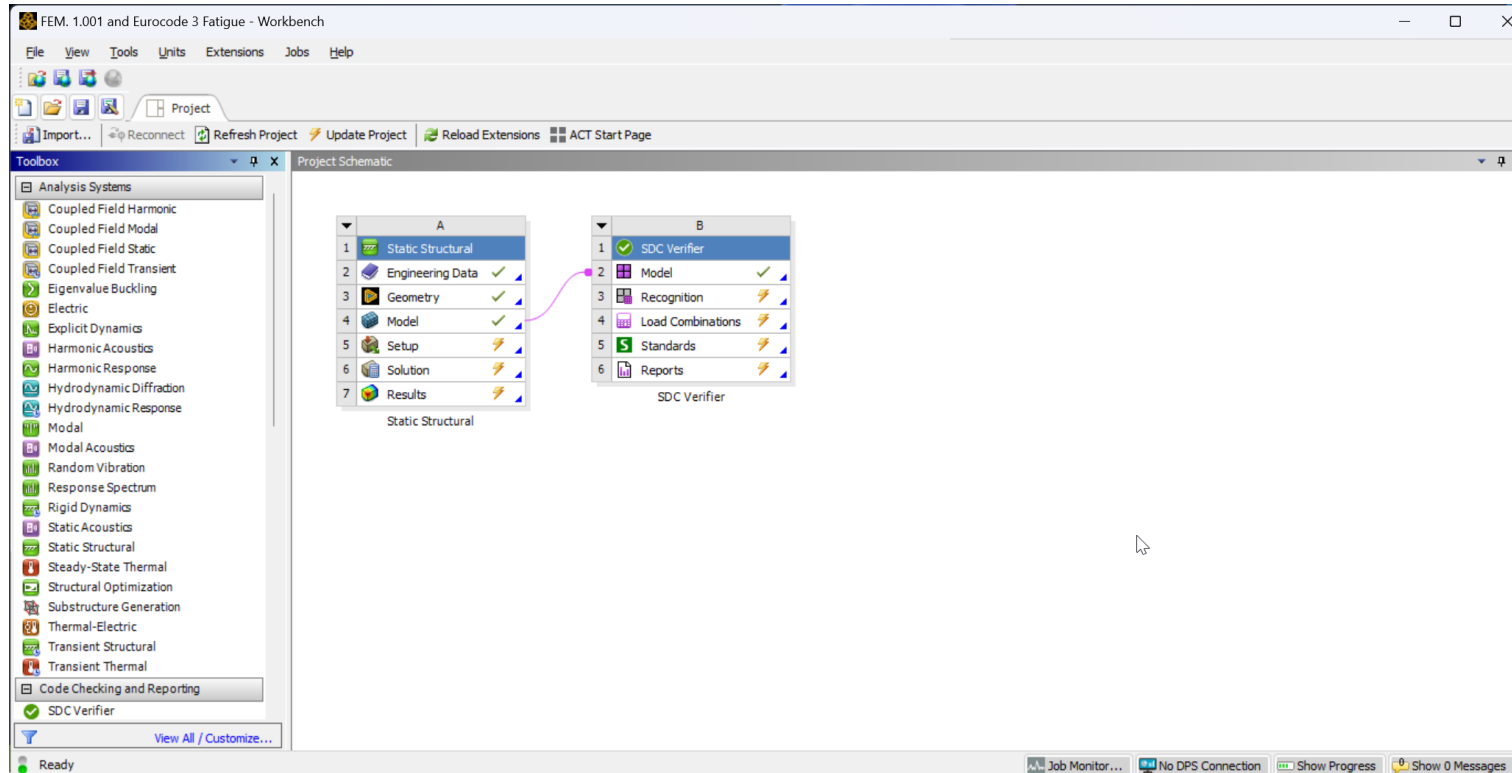
2

Double Click on  Model or in context menu click **Edit**

2

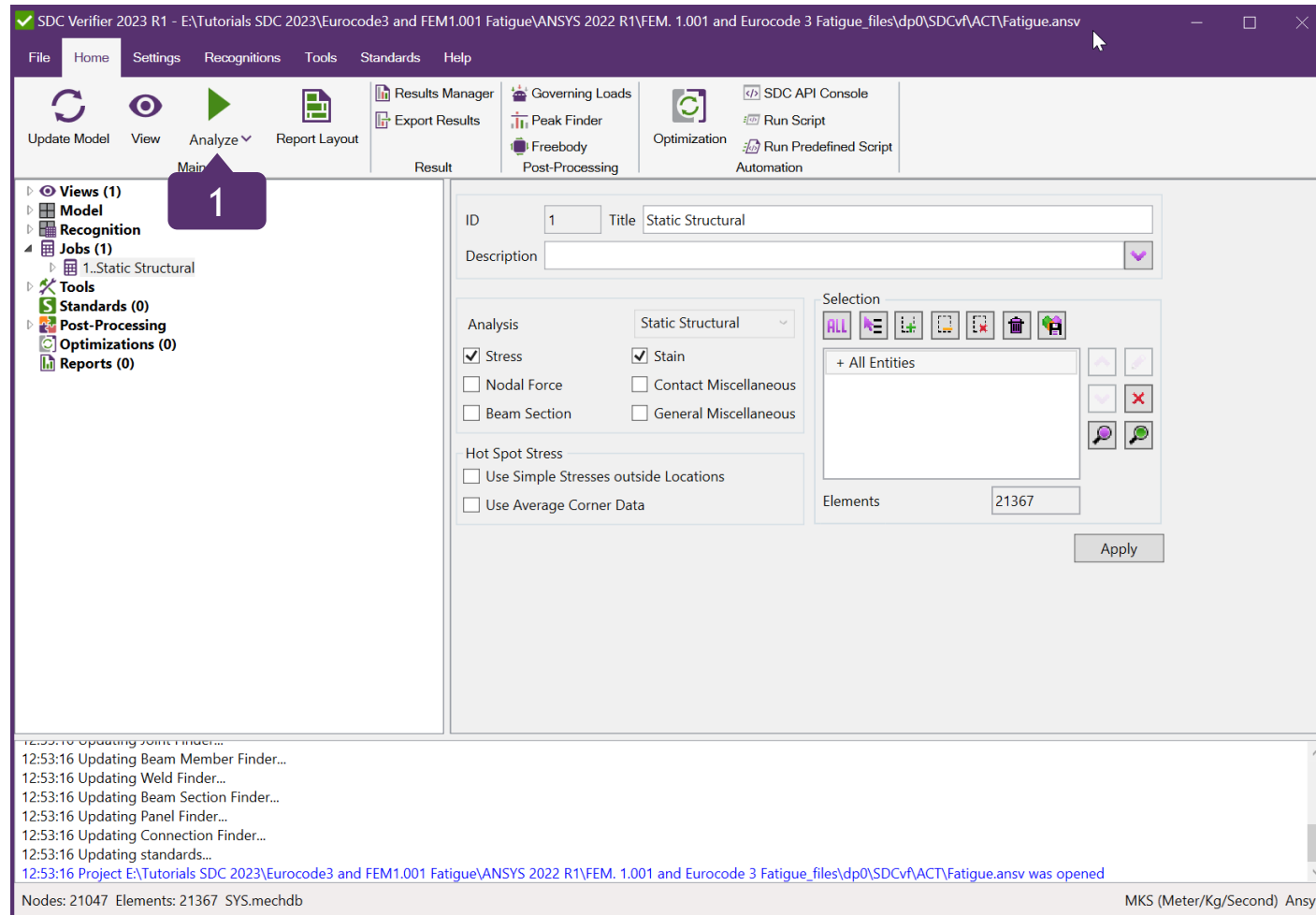


SDC Verifier



1

Press  to start Analysis in ANSYS




1

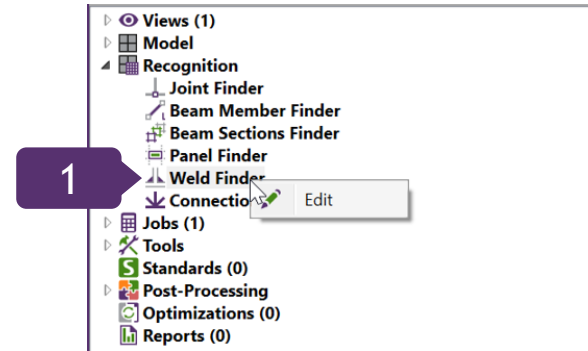
Execute Recognition => **Weld Finder** => Edit...

2

Press *Find*.

3

Press  to Export selected welds to components



Welds Finder

Welds | Weld Strength Settings | Hot Spot Stress

Filter: None | Apply Filter

Find Weld by ID: | Navigate

ID	Title	Tensile Strength (Min) [Pa]	Yield Stress (Min) [Pa]	Is Symmetric	Is curved	Nodes	Elements	Weld Parts
1	Weld 1 [0.5; 1.09; -1.05]	0	0	Yes	Yes	39	76	2
2	Weld 2 [0.5; 0.15; -2.64]	0	0	Yes	No	5	12	3
3	Weld 3 [0.5; 0.37; -2.64]	0	0	Yes	No	5	12	3
4	Weld 4 [-0.5; 1.09; -1.05]	0	0	Yes	Yes	39	76	2
5	Weld 5 [-0.51; 0.48; -8.7]	0	0	No	No	2	2	2
6	Weld 6 [0.51; 0.48; -8.7]	0	0	No	No	2	2	2
7	Weld 7 [-0.5; 0.69; -2.64]	0	0	Yes	No	5	12	3
8	Weld 8 [0.5; 0.69; -2.64]	0	0	Yes	No	5	12	3
9	Weld 9 [-0.5; 0.37; -2.64]	0	0	Yes	No	5	12	3
10	Weld 10 [-0.5; 0.15; -2.64]	0	0	Yes	No	5	12	3
11	Weld 11 [-0.5; 1.52; -2.75]	0	0	Yes	No	10	27	3
12	Weld 12 [-0.5; 0.69; -2.75]	0	0	Yes	No	2	3	3
13	Weld 13 [-0.5; 0.53; -2.75]	0	0	Yes	No	7	18	3
14	Weld 14 [-0.5; 0.26; -2.75]	0	0	Yes	No	5	12	3
15	Weld 15 [-0.5; 0.08; -2.75]	0	0	Yes	No	4	9	3
16	Weld 16 [-0.5; 1.43; -2.08]	0	0	Yes	No	14	39	3
17	Weld 17 [-0.5; 0.92; -2.08]	0	0	Yes	No	7	24	4
18	Weld 18 [-0.5; 0.38; -2.08]	0	0	Yes	No	15	42	3
19	Weld 19 [0.5; 0.08; -2.75]	0	0	Yes	No	4	9	3
20	Weld 20 [0.5; 0.26; -2.75]	0	0	Yes	No	5	12	3
21	Weld 21 [0.5; 0.53; -2.75]	0	0	Yes	No	7	18	3
22	Weld 22 [0.5; 0.69; -2.75]	0	0	Yes	No	2	3	3
23	Weld 23 [0.5; 0.37; -2.64]	0	0	Yes	No	10	27	3
24	Weld 24 [0.5; 0.15; -2.64]	0	0	Yes	No	14	39	3
25	Weld 25 [0.5; 0.08; -2.75]	0	0	Yes	No	7	24	4

Settings | Find

Set Parameter | Check on Weld Design

OK | Cancel

Add, Edit, Combine and Remove Welds

Move Welds. Order is important when one element belongs to 2 welds.

Select element and highlight respective welds in the table

Preview selected welds

Plot of selected welds in colors and with labels of IDs

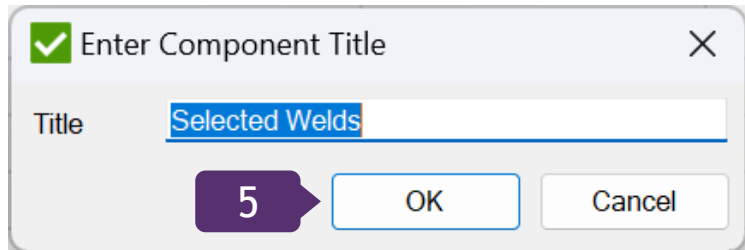
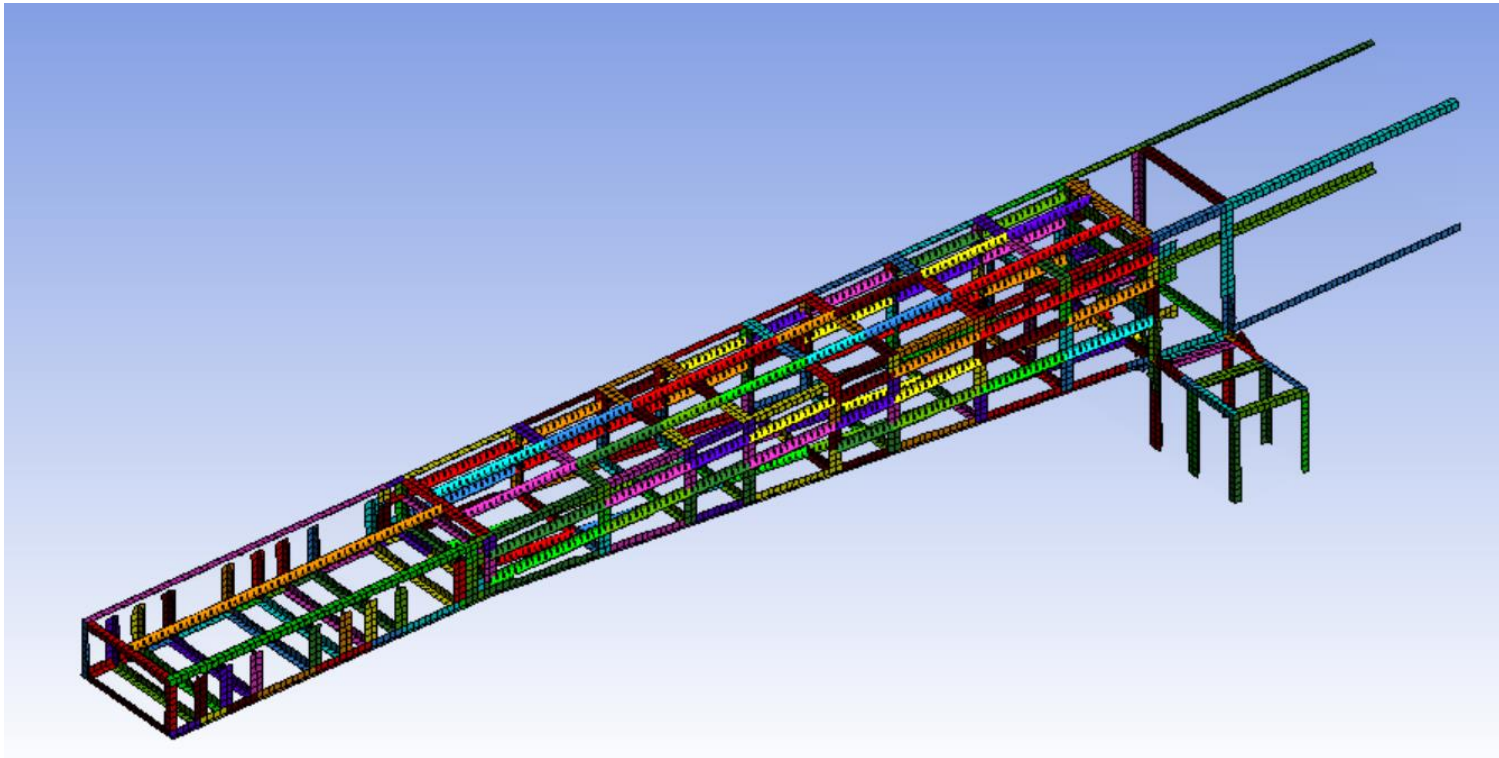
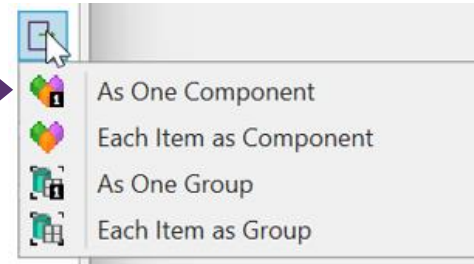
4

Click *As One Component*

5

Press *OK*.

4



New component will be created.

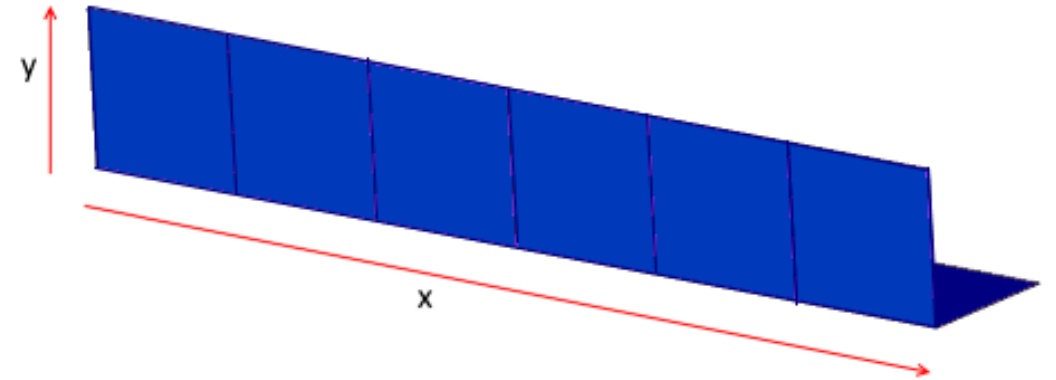
Stresses for weld elements are automatically transformed in the direction of the corresponding weld from Weld Finder Tool using the wedge method. Stresses are transformed only for plate type elements.

$$\sigma_{nn} = \frac{(\sigma_{xx} + \sigma_{yy})}{2} + \frac{(\sigma_{xx} - \sigma_{yy})}{2} * \cos 2\theta + \tau_{xy} * \sin 2\theta$$

$$\tau_{nt} = -\frac{(\sigma_{xx} - \sigma_{yy})}{2} * \sin 2\theta + \tau_{xy} * \cos 2\theta$$

$$\sigma_{tt} = \frac{(\sigma_{xx} + \sigma_{yy})}{2} - \frac{(\sigma_{xx} - \sigma_{yy})}{2} * \cos 2\theta - \tau_{xy} * \sin 2\theta$$

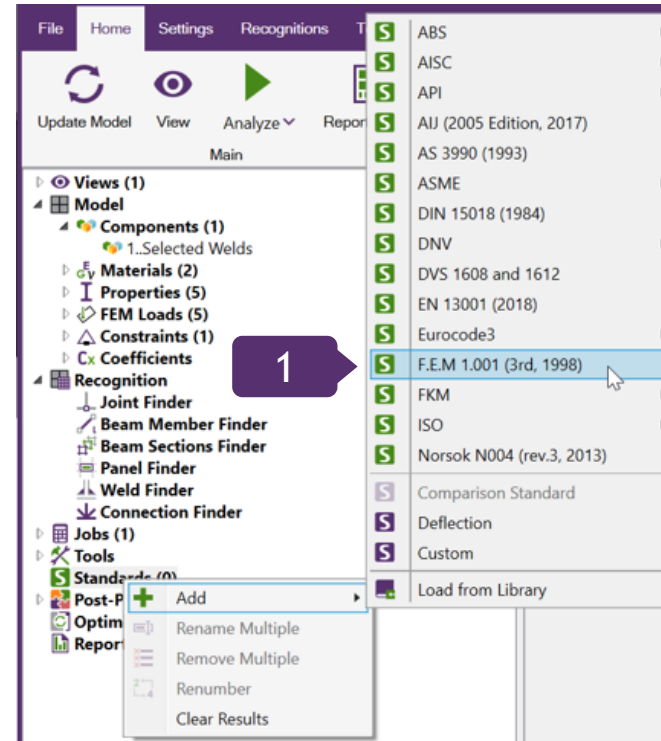
$\sigma_{xx}, \sigma_{yy}, \tau_{xy}$ - original x, y and shear stress in local element x, y and shear directions
 $\sigma_{tt}, \sigma_{nn}, \tau_{nt}$ - transformed x, y and shear stress in weld x, y and shear directions
 θ - angle between the element and weld x directions.



Add FEM 1.001 standard

1

Execute *Add* => **F.E.M. 1.001** in Standards context menu.



F.E.M. 1.001 - performs static stress check and fatigue check for steel structures of crane and crane equipment. Fatigue calculations are performed according to Allowable Stress Design method (ASD).

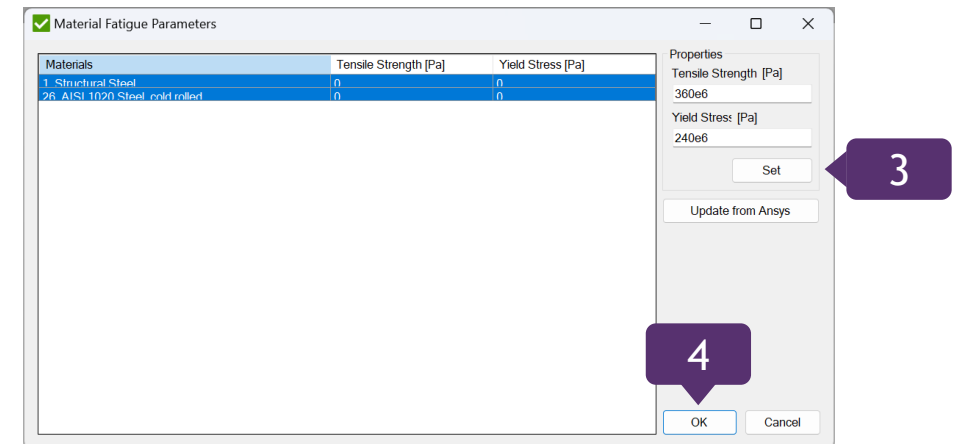
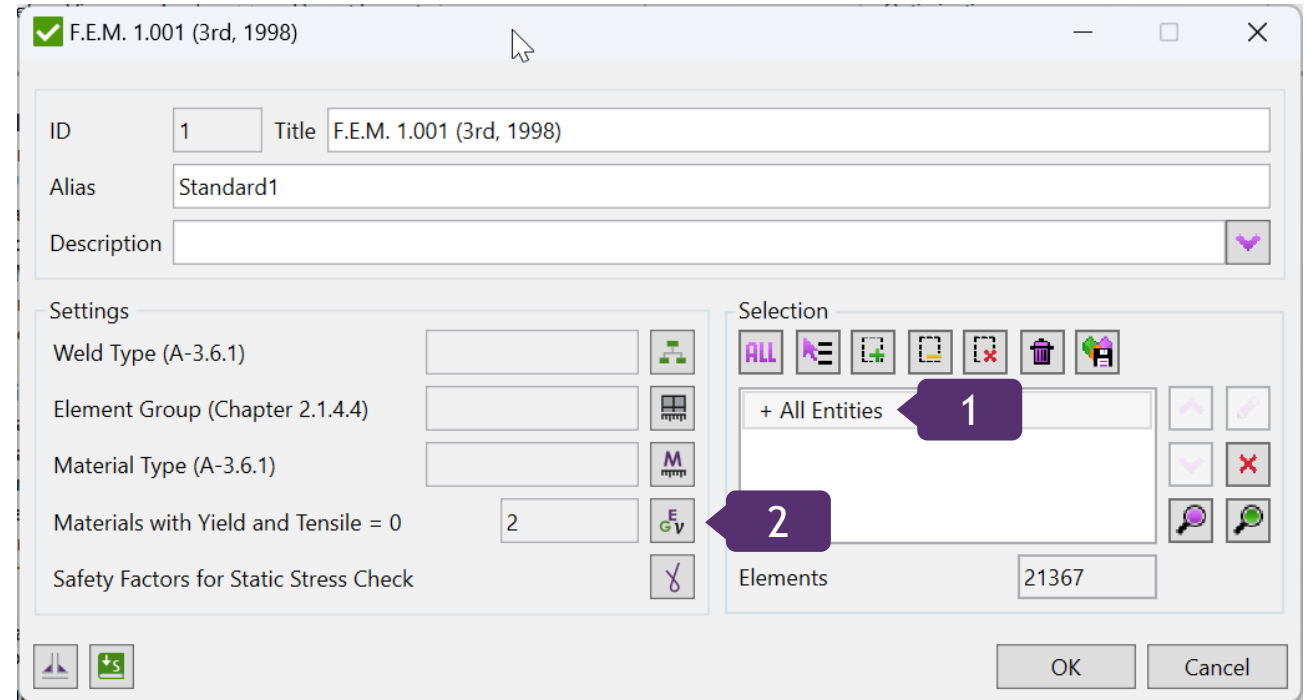
1 Selection: All Entities

2 Press  to edit material properties.

Amount of materials with not defined Tensile or Yield is displayed in the field

3 Tensile Strength: **360e6**
Yield Stress: **240e6** and Press **Set**.


4 Press **OK**.



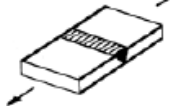


- Weld/notch category determines fatigue resistance
- Division in welds / non welds for FEM 1.001:
 - W category is for non welded parts
 - K category is for welded parts
- Fatigue resistance is further specified by adding classes
 - W0-W2 for non-welded parts
 - K0-K4 for welded parts
- Better fatigue resistance results in lower class number

Weld Classes depends on Weld Type




Non-weld group W0

nr.	description of the main types		symbol
W01	Part without hole and without joint, with a normal state of the surface, without notch behaviour.		—

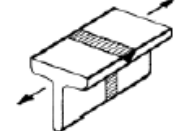


Slight notch behavior group K0

nr.	description of the main types		symbol
011	Parts, jointed by a butt weld of special quality, perpendicular to the direction of force.		 P 100  P 100


Moderate notch behavior group K1

nr.	description of the main types		symbol
111	Parts, jointed by a butt weld of ordinary quality, perpendicular to the direction of force.		 P or P 100  P or P 100

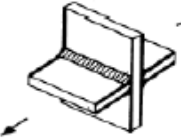
Medium notch behavior group K2

nr.	description of the main types		symbol
211	Profiles, jointed by butt welds of special quality, perpendicular to the direction of force.		 P 100  P 100




Great notch behavior group K3

311	Parts jointed by a butt weld with a backing strap, without sealing run and perpendicular to the direction of force. Backing strap fixed by tack welding.		>
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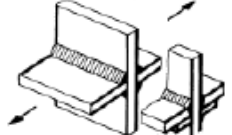


and a different connection type 351

nr.	description of the main types		symbol
351	Double bevel weld of ordinary quality, perpendicular to the direction of force, between crossing parts.		∇ D

Very great notch behavior group K4

nr.	description of the main types		symbol
412	Parts of different thickness, jointed by a butt weld of ordinary quality, perpendicular to the direction of force. Asymmetrical joint without slope.		 P  P

and a different connection type 451

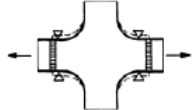


451	Fillet welds of normal quality or single bevel weld (included fillet weld) with backing, perpendicular to the direction of force, between crossing parts.		 D  D
-----	---	---	--

	Perpendicular to weld	Parallel with weld	Shear
Weld	K1	K2	K0
No weld	W0		$\tau_D(-1) = \sigma_D(-1) / \text{sqrt}(3)$

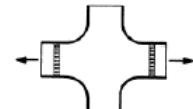


Steel Grade	$\sigma_D(-1)$ for $\kappa=-1$ element group 5 St 52-3							
Notch group	W0	W1	W2	K0	K1	K2	K3	K4
Stress amplitude	163.8	130.3	104.2	118.8	106.1	89.1	63.6	38.2

Depends on Stress concentrations:

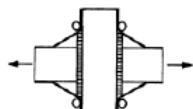


Slight notch behavior group K0

013	Gusset, jointed by butt welds of special quality, perpendicular to the direction of force.		 P 100  P 100
-----	--	---	--

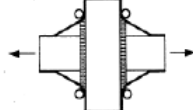


Moderate notch behavior group K1

113	Gusset, jointed by butt welds of ordinary quality, perpendicular to the direction of force.		 P or P 100  P or P 100
-----	---	---	--

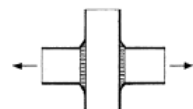


Medium notch behavior group K2

213	Butt weld of special quality and continuous part, both perpendicular to the direction of force, at a crossing of flanges with in-welded corner plates. The ends of the welds are ground to prevent them from notch behaviour.		 P 100  P 100
-----	---	---	--

Great notch behavior group K3


313	Butt weld of ordinary quality and continuous part both perpendicular to the direction of force, at a crossing of flanges with welded corner plates. The ends of the welds have been ground to prevent them from notch behaviour.		 P or P 100  P or P 100
-----	--	--	--

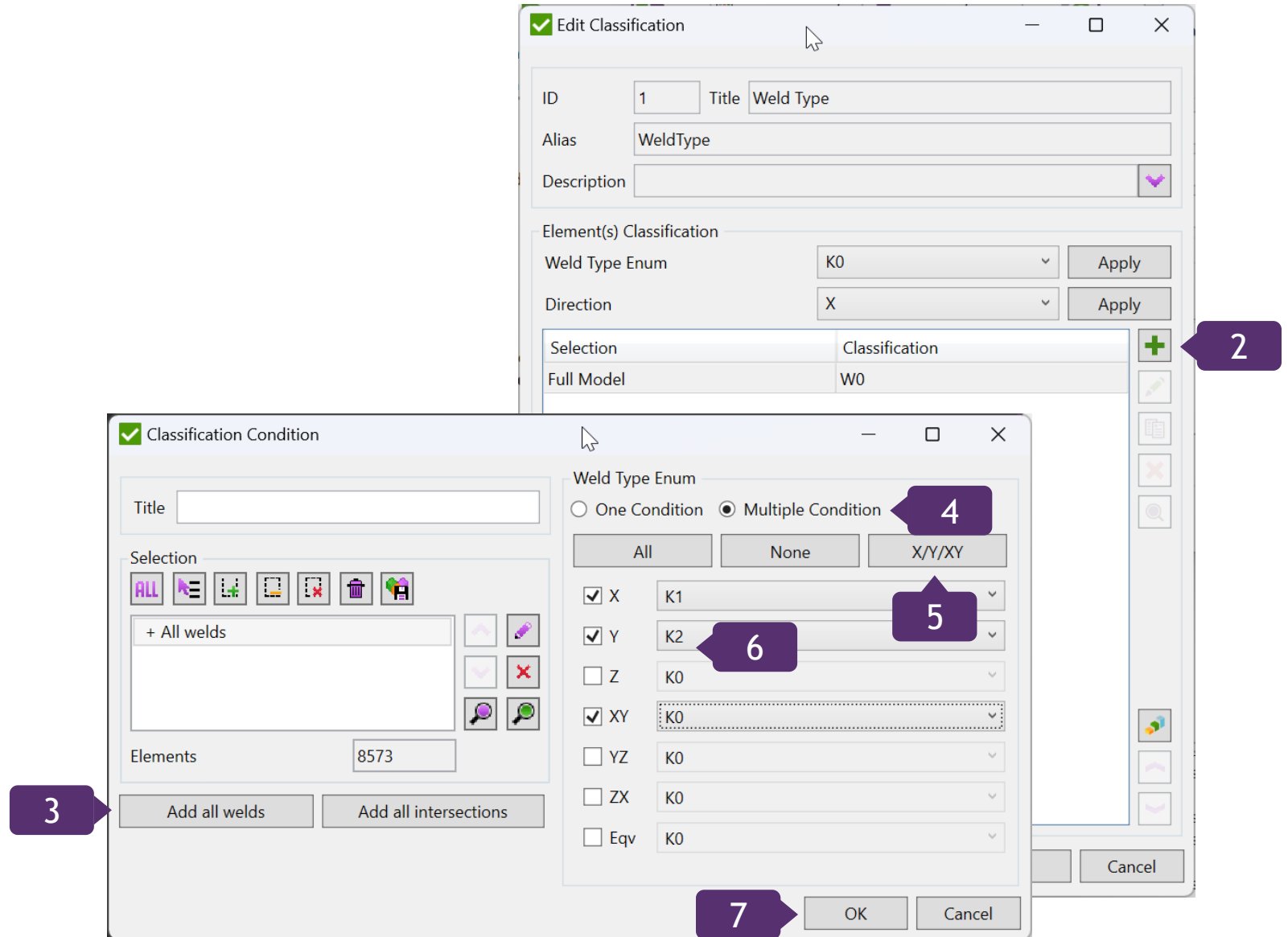
Very great notch behavior group K4

413	Butt weld of ordinary quality, perpendicular to the direction of force, at a crossing of flanges without corner plates.		 P  P
-----	---	---	--

(not included in this tutorial)

Weld Type Classification

- 1 Press *Define* for the Weld Type.
- 2 Press  to Add Condition.
- 3 Press *Add all Welds*
- 4 Select *Multiple Conditions* options
- 5 Press *X/Y/XY*
- 6 X: K1 Y: K2 XY: K0
- 7 Press *OK*



Weld Type classification intersecting welds

1 Press  to Add Condition.

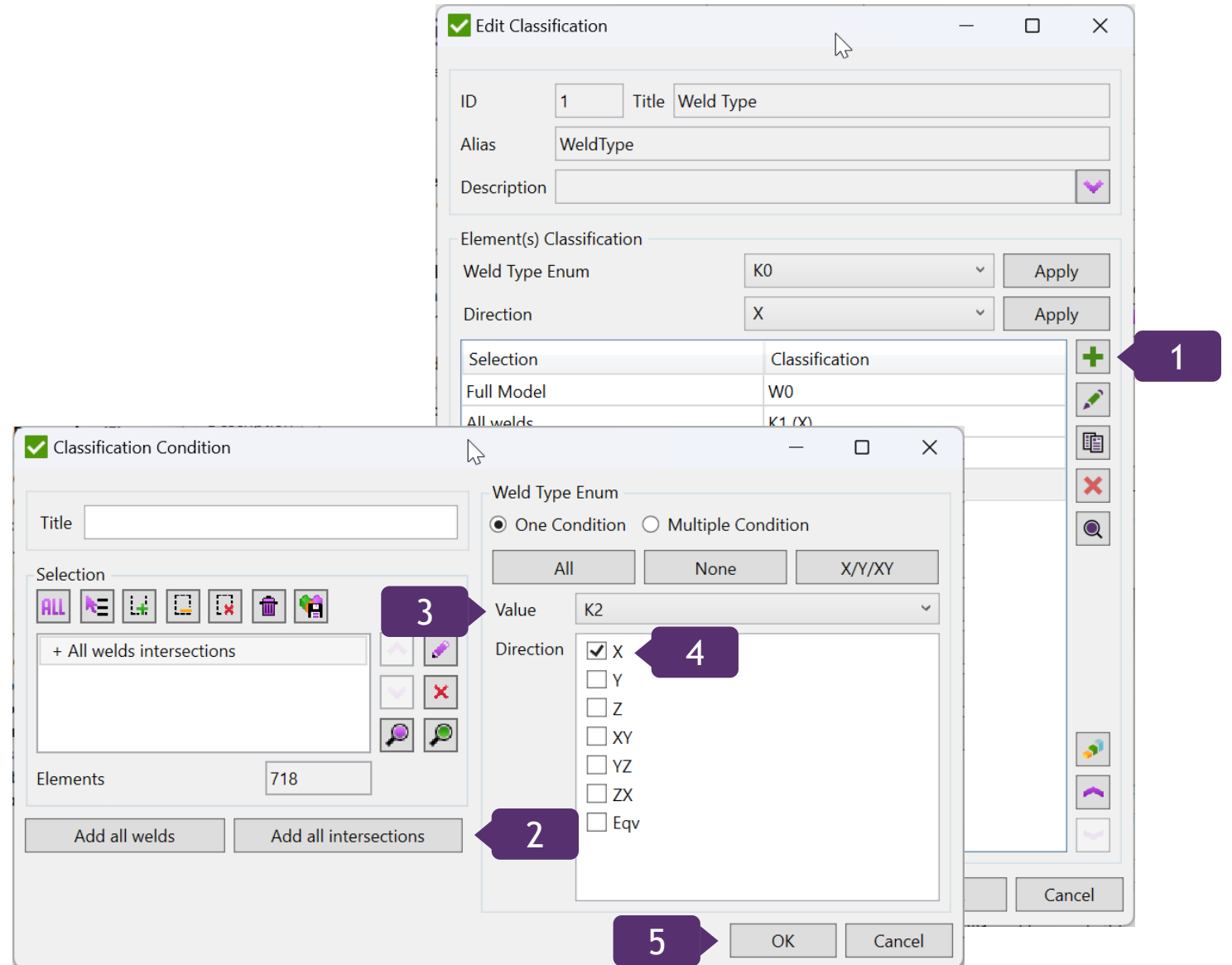
2 Click *Add all welds intersections*

3 Value: K2

4 Directions: X

5 Press *OK*

At intersecting welds all stresses are perpendicular to the weld direction. The last condition overwrites the previous ones and settings in condition 2 => K1(X) are replaced with K2(X) for intersections



✓ Edit Classification

ID1TitleWeld Type

AliasWeldType

Description

Element(s) Classification

Weld Type EnumK0Apply

DirectionXApply

Selection	Classification
Full Model	W0
All welds	K1 (X)
All welds	K2 (Y)
All welds	K0 (XY)
All welds intersections	K2 (X)

Import Welds

Clear

OK

Cancel

Selection

+ All Entities

Elements2136

Values

LabelsX1

Selection

2

14:38:17 E:\Tutorials SDC 2023\Eurocode3 and FEM1.001 Fatigue\ANSYS 2022 R1\FEM. 1.001 and Eurocode 3

14:38:17 E:\Tutorials SDC 2023\Eurocode3 and FEM1.001 Fatigue\ANSYS 2022 R1\FEM. 1.001 and Eurocode 3

14:53:16 Saving backup file...

14:53:17 E:\Tutorials SDC 2023\Eurocode3 and FEM1.001 Fatigue\ANSYS 2022 R1\FEM. 1.001 and Eurocode 3

14:53:17 E:\Tutorials SDC 2023\Eurocode3 and FEM1.001 Fatigue\ANSYS 2022 R1\FEM. 1.001 and Eurocode 3

1

A 3D finite element model of a welded structure, possibly a beam-to-column joint. The model is composed of a mesh of elements. Three labels are visible: a blue label 'K1' at the left end, a yellow label 'K2' in the middle, and a cyan label 'W0' at the right end.

2

The same 3D model as above, but with different classification labels. A blue label 'K2' is at the left end, and a yellow label 'W0' is in the middle. The right end is no longer labeled.

21

<https://sdcverifier.com>

Element Group classification

1

Press  for the Element Group.

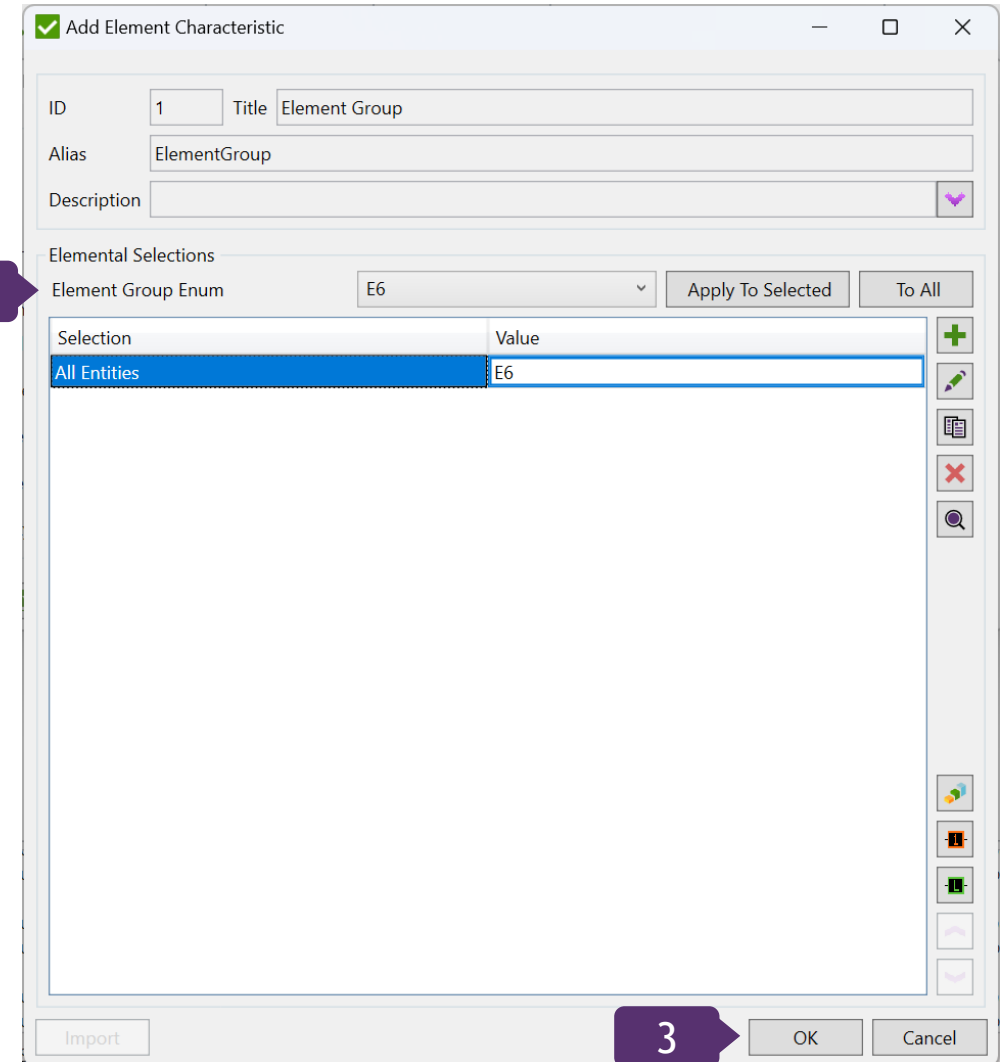
2

Select Element Group: **E6**. Press *To All*.

3

Press *OK*.


2




✓ Add Element Characteristic

ID: 1 Title: Element Group

Alias: ElementGroup

Description: 

Elemental Selections

Element Group Enum: E6  Apply To Selected To All

Selection	Value
All Entities	E6

Import OK Cancel

Material Type classification

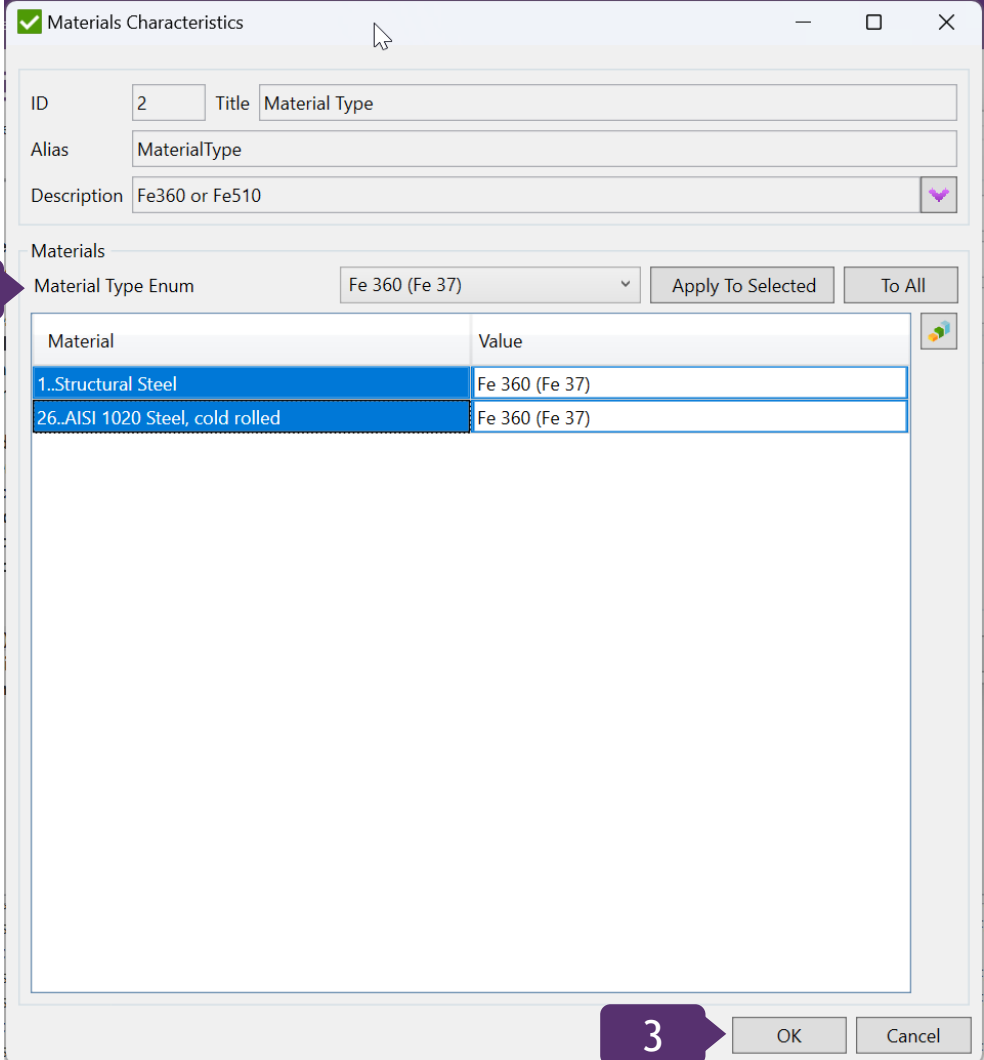
1 Press  for the Material Type.

2 Select Material Type: **Fe360 (Fe 37)**.
Press *To All*.

3 Press *OK*.

4 Press *OK* to create Standard.

Material Type defines which steel is used: St37 or St52. Stress Fatigue values are different for different materials.




The dialog box 'Materials Characteristics' is shown. It has fields for ID (2), Title (Material Type), Alias (MaterialType), and Description (Fe360 or Fe510). Below these is a 'Materials' section with a 'Material Type Enum' dropdown set to 'Fe 360 (Fe 37)' and buttons 'Apply To Selected' and 'To All'. A table below shows two materials: '1..Structural Steel' and '26..AISI 1020 Steel, cold rolled', both with the value 'Fe 360 (Fe 37)'. At the bottom are 'OK' and 'Cancel' buttons.

Material	Value
1..Structural Steel	Fe 360 (Fe 37)
26..AISI 1020 Steel, cold rolled	Fe 360 (Fe 37)

Create extreme table

1

Execute  *Table (expand/extreme)* in Fatigue Check context menu.

2

Load: 1..Load Group1.

Fatigue check supports only Load Groups. If only one load group exist in the project it will be selected automatically.

3

Table structure: **Parameter over Directions.**

4

Parameter: **Utilization Factor.**

5

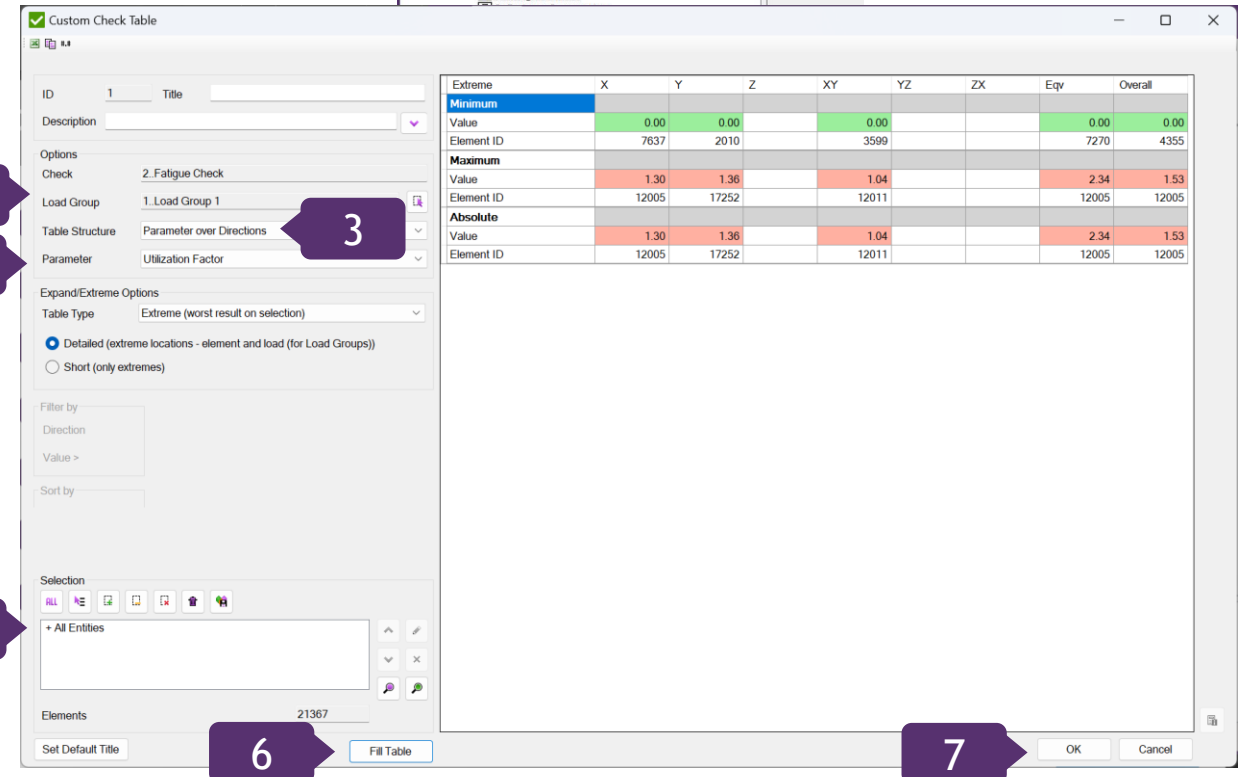
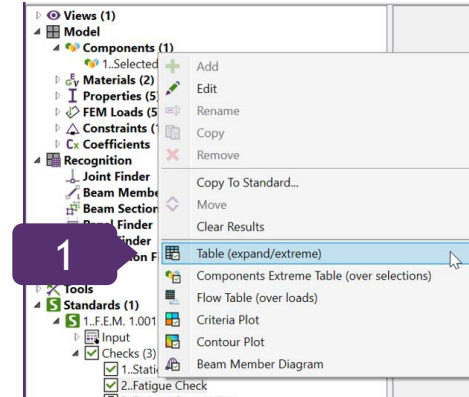
Selection: **All Entities.**

6

Press *Fill Table*.


7

Press *OK*.



Create criteria plot

1

Execute  Criteria Plot in **Fatigue Check** context menu.

2

Parameter: **Utilization Factor**

3

Direction: **Overall**

4

Point of interest: **Total** Type: **AbsMax**

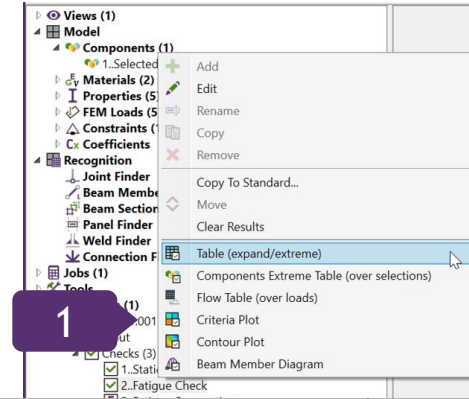
5

Press  *Preview*

6

Press OK

Point of interest = AbsMax Total is absolute maximum utilization factors among all point of interest.



2

4

3

6

5

Criteria Plot

ID: 1 Title:

Description:

Options

Check: 2..Fatigue Check

Load Group: 1..Load Group 1

Parameter: Utilization Factor

Direction: Overall

LG Parameter: Absolute

Point Of Interest: Total Type: AbsMax

View: 1..Default View

Selection

ALL

+ All Entities

Elements: 21367

Labels: None

Limits:

Set Default Title

Preview (5) OK (6) Cancel

Report. Tables and plots

1

Execute *Reports* => *Add Report Designer* => *Results*.

2

Click on *Check Tables* in **Results** tab of the tool bar.

3

Select *Fatigue Check* in the list of standard checks and press button

4

Load Group: 1..Load Group

5

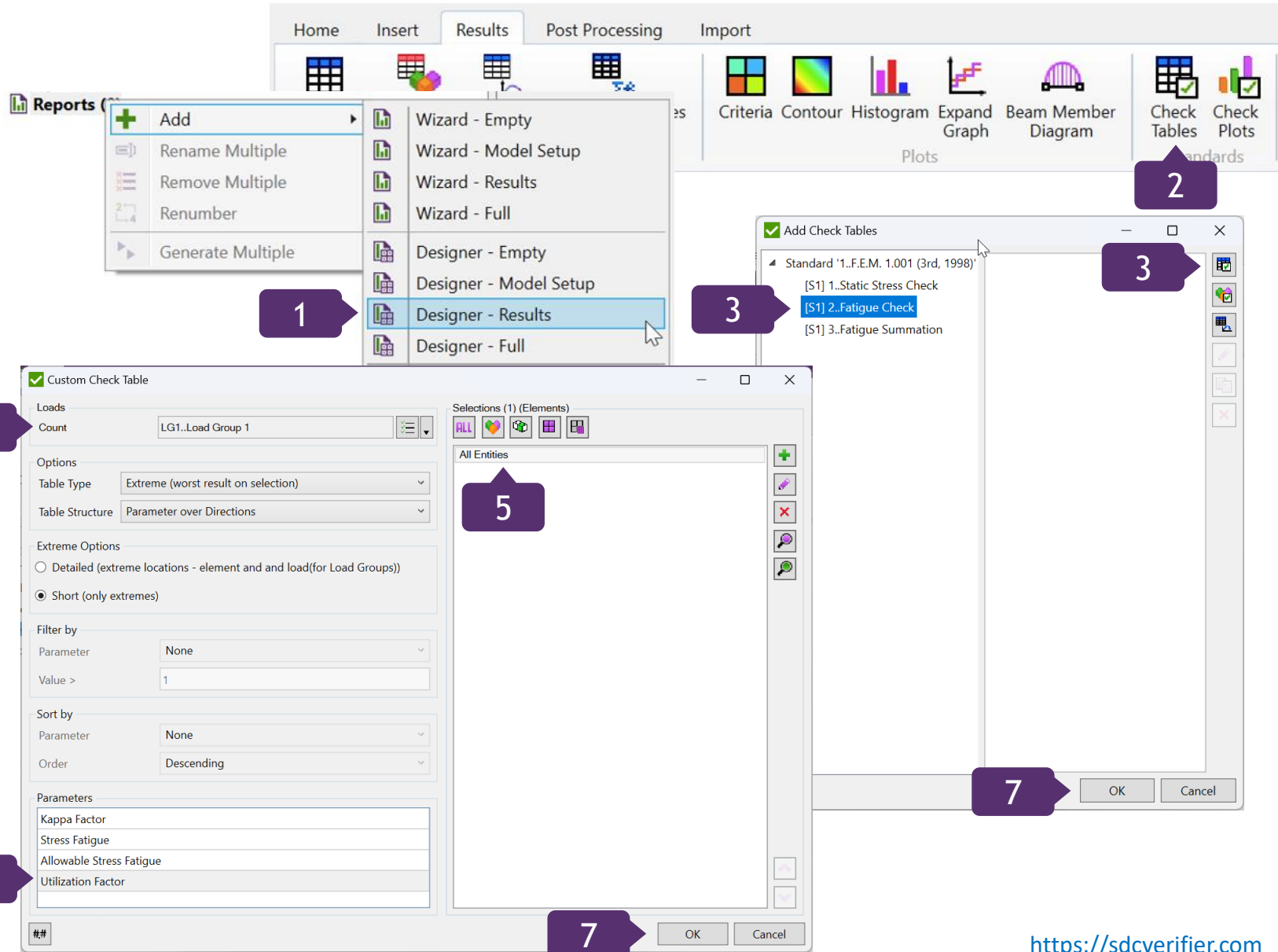
Selection: *All Entities*.

6

Parameter: *Utilization Factor*.

7

Press *OK*.




Report. Tables and plots

1

Click on *Check Plots* in **Results** tab of the tool bar.

2

Select ***Fatigue Check*** in the list of standard checks and press button 

3

Load Group: **1..Load Group**

4

Parameter: ***Utilization Factor***.

5

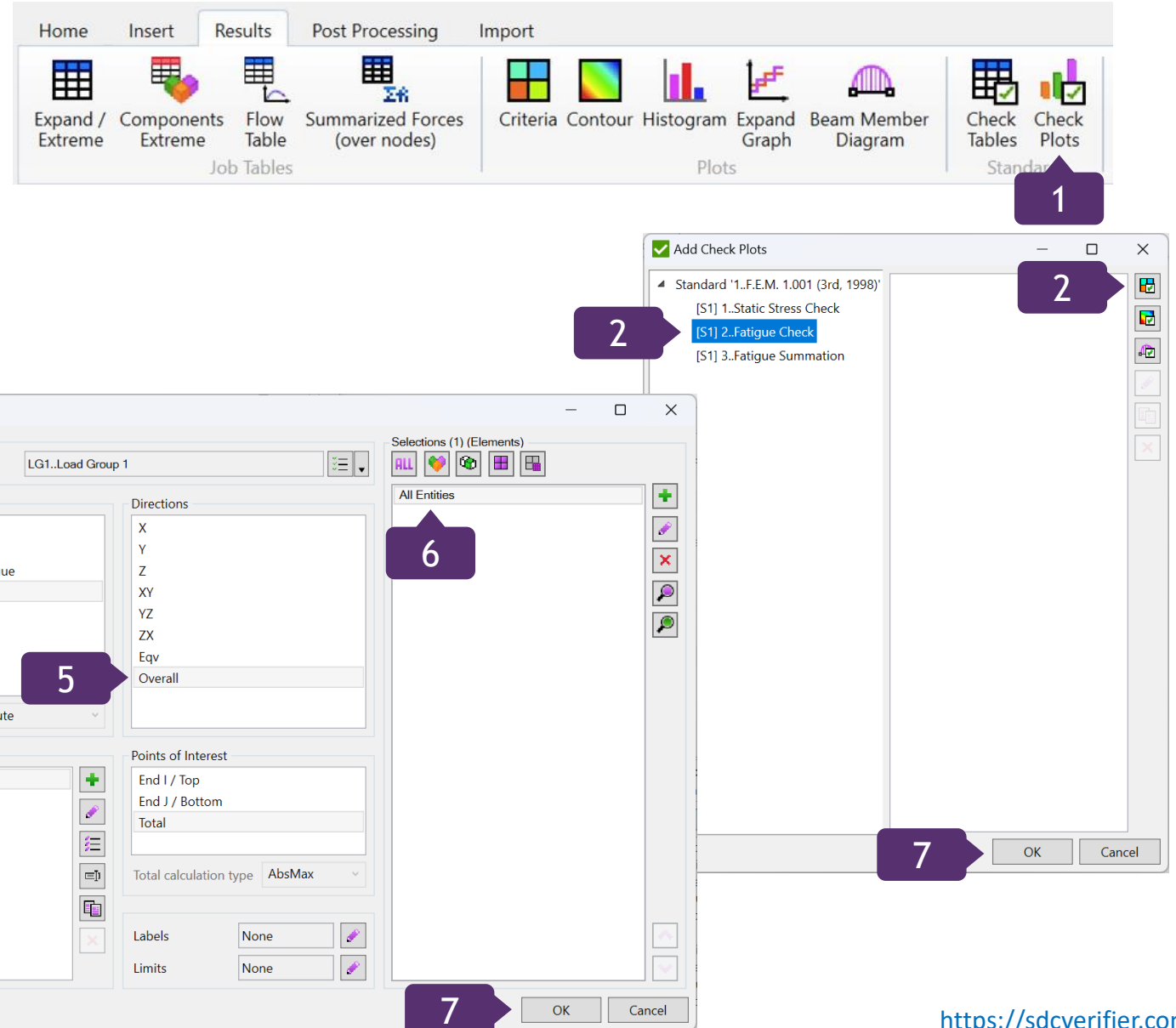
Direction: ***Overall***.

6

Selection: ***All Entities***.

7

Press **OK**.



2..Fatigue Check

Property	Value
Category	Elemental Custom Check
Selection	All Entities
Parameters	4
Alias (Parameter)	Kappa (Kappa Factor)
Description	Ratio between the extreme stresses
All	$\text{if}(\text{SweldAbs} > 0, \text{SweldMin} / \text{SweldMax}, \text{SweldMax} / \text{SweldMin})$
Alias (Parameter)	Sf (Stress Fatigue)
Description	Permissible stress for fatigue depends on the element group (E1-E8) and weld type
All	$\text{Min}(\text{units.FromPaToCurrent}(\text{Switch}(\text{MaterialType}, \text{MaterialTypeEnum.Fe360Fe37}, \text{Sf_Fe360}(\text{ElementGroup}, \text{WeldType}), \text{MaterialTypeEnum.Fe510Fe52}, \text{Sf_Fe510}(\text{ElementGroup}, \text{WeldType}))), 0.75 * \text{Tensile})$
Alias (Parameter)	Sallow_fatigue (Allowable Stress Fatigue)
Description	Appendix 3.6, formulas (1)-(4)
All	$\text{if}(\text{Kappa} > 0, \text{if}(\text{SweldAbs} > 0, 1, 1.2) * (5 / 3 * \text{Sf}) / (1 - (1 - (5 / 3 * \text{Sf}) / (0.75 * \text{tensile})) * \text{Kappa}), \text{if}(\text{SweldAbs} > 0, (5 * \text{Sf}) / (3 - 2 * \text{Kappa}), (2 * \text{Sf}) / (1 - \text{Kappa})))$
XY/YZ/ZX	$\text{if}(\text{Kappa} > 0, (5 / 3 * \text{Sf}) / (1 - (1 - (5 / 3 * \text{Sf}) / (0.75 * \text{tensile})) * \text{Kappa}), (5 * \text{Sf}) / (3 - 2 * \text{Kappa})) / \text{if}(\text{WeldType} \leq \text{WeldTypeEnum.K4}, \text{SQRT}(2), \text{SQRT}(3))$
Eqv	0
Alias (Parameter)	Uf (Utilization Factor)
Description	Appendix 3.6, equivalent rule - (5)
All	$\text{Abs}(\text{SweldAbs}) / \text{Sallow_Fatigue}$
Eqv	$\text{pow}(\text{me.x}, 2) + \text{pow}(\text{me.y}, 2) + \text{pow}(\text{me.z}, 2) + \text{pow}(\text{me.xy}, 2) + \text{pow}(\text{me.yz}, 2) + \text{pow}(\text{me.zx}, 2) - \text{sign}(\text{SweldAbs.X}) * \text{me.x} * \text{sign}(\text{SweldAbs.Y}) * \text{me.y} - \text{sign}(\text{SweldAbs.Y}) * \text{me.y} * \text{sign}(\text{SweldAbs.Z}) * \text{me.z} - \text{sign}(\text{SweldAbs.Z}) * \text{me.z} * \text{sign}(\text{SweldAbs.X}) * \text{me.x}$
Overall	$\text{Max}(\text{me.x}, \text{me.y}, \text{me.z}, \text{me.xy}, \text{me.yz}, \text{me.zx}, \text{sqrt}(\text{me.eqv}))$

1..F.E.M. 1.001 (3rd, 1998)

Unit System

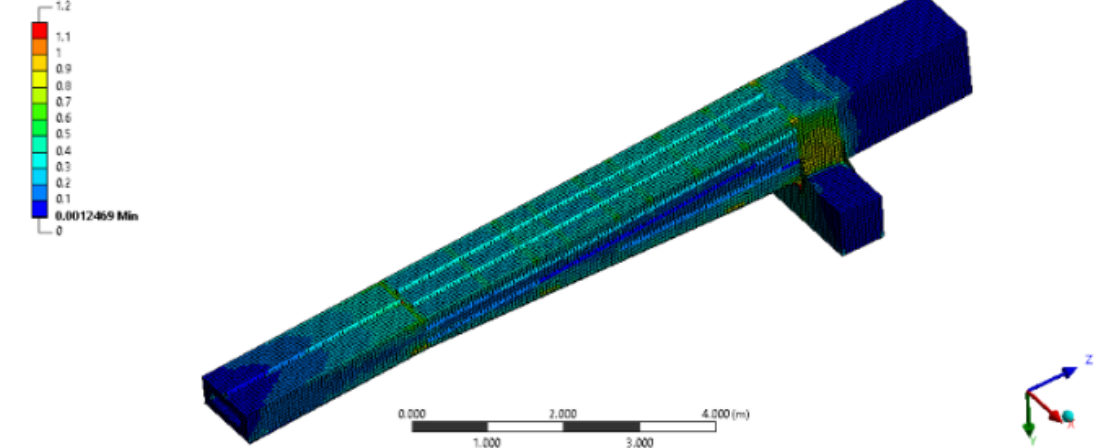
Current Unit System = MKS (Meter/Kg/Second). It is used in calculations for the following standards: API RP 2A, ISO 19902, Norsok N004, DIN 15018, FEM 1.001 and Eurocode3.

Utilization Factor (LG1, All Entities)

Standard	1..F.E.M. 1.001 (3rd, 1998)			Check	[S1] 2..Fatigue Check			
Load Group	LG1..Load Group 1			Parameter	Utilization Factor			
Selection	All Entities							
Extreme	X	Y	Z	XY	YZ	ZX	Eqv	Overall
Minimum	0.00	0.00		0.00			0.00	0.00
Maximum	1.30	1.36		1.04			2.34	1.53
Absolute	1.30	1.36		1.04			2.34	1.53

Overall Utilization Factor (LG1, All Entities, v1, Total)

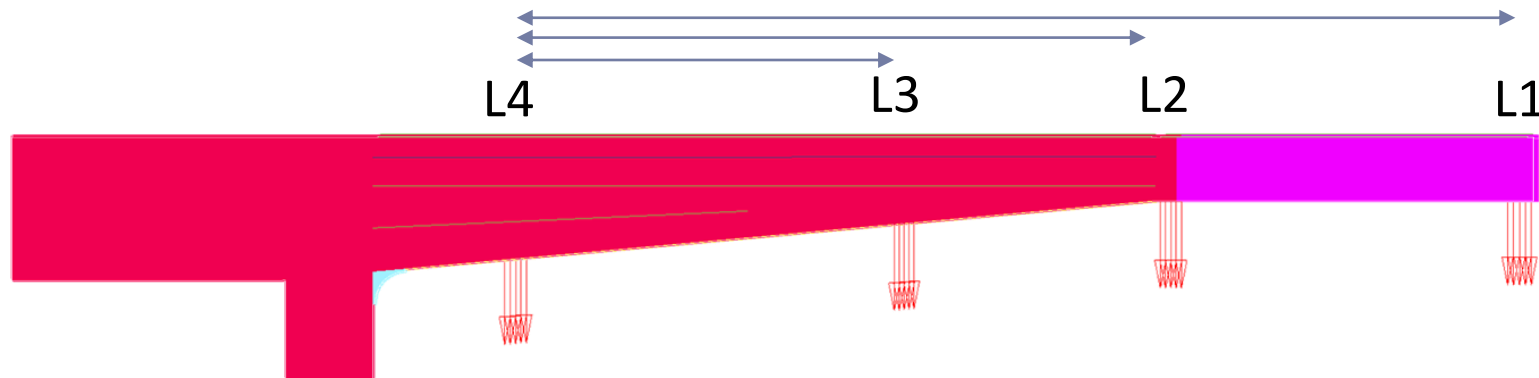
As Static Structural
Overall Utilization Factor (LG1, All Entities, v1, Total)
Expression: RES40 (Scoped to Elements)
Time: 5 s
14-Apr-23 12:54



Check	[S1] 2..Fatigue Check	Point	Total
Load Group	LG1..Load Group 1	Parameter	Overall Utilization Factor
Selection	All Entities	View	1..Default View

- A better fatigue damage can be made if load cycles are specified more accurately.
- Instead of 2 million load cycles from start to end:

Load cycle	Number of cycles	Content
L4-L1	0,5 e6	LS4, LS3, LS2, LS1, IL1
L4-L2	1,0 e6	LS4, LS3, LS2, IL1
L4-L3	0,5 e6	LS4, LS3, IL1



NB: gravity load is also included because the stress variation determines the fatigue damage

Add Fatigue Group (stress history)

1 Select **Fatigue Groups** in Navigation tree

2 Title: **Detailed load cycles pattern**

3 Select all groups and press

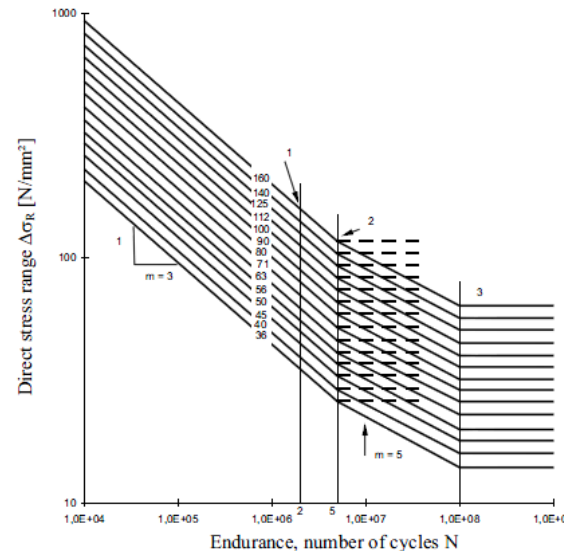
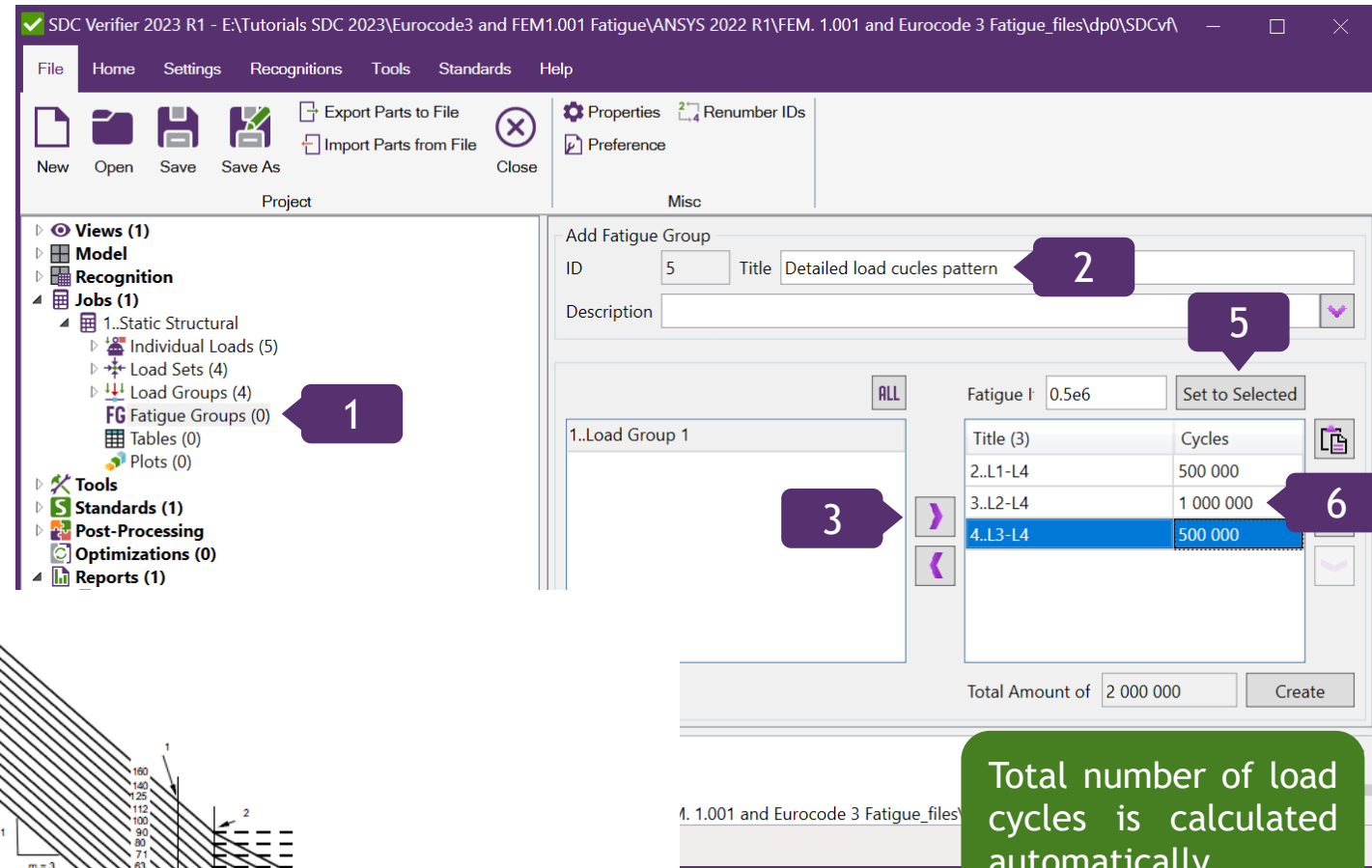


4 Select 1..L1-L4 and 3..L2-L4

5 Fatigue Item Cycles: **0.5e+6** and *Set to Selected*.

6 Set **1e+6** cycles for 2..L3-L4

7 Press *Create*



1

Execute *Add* => **Eurocode 3 Fatigue (EN 1993-1-9)** in Standards context menu.

2

Consequence of Failure: **Low**

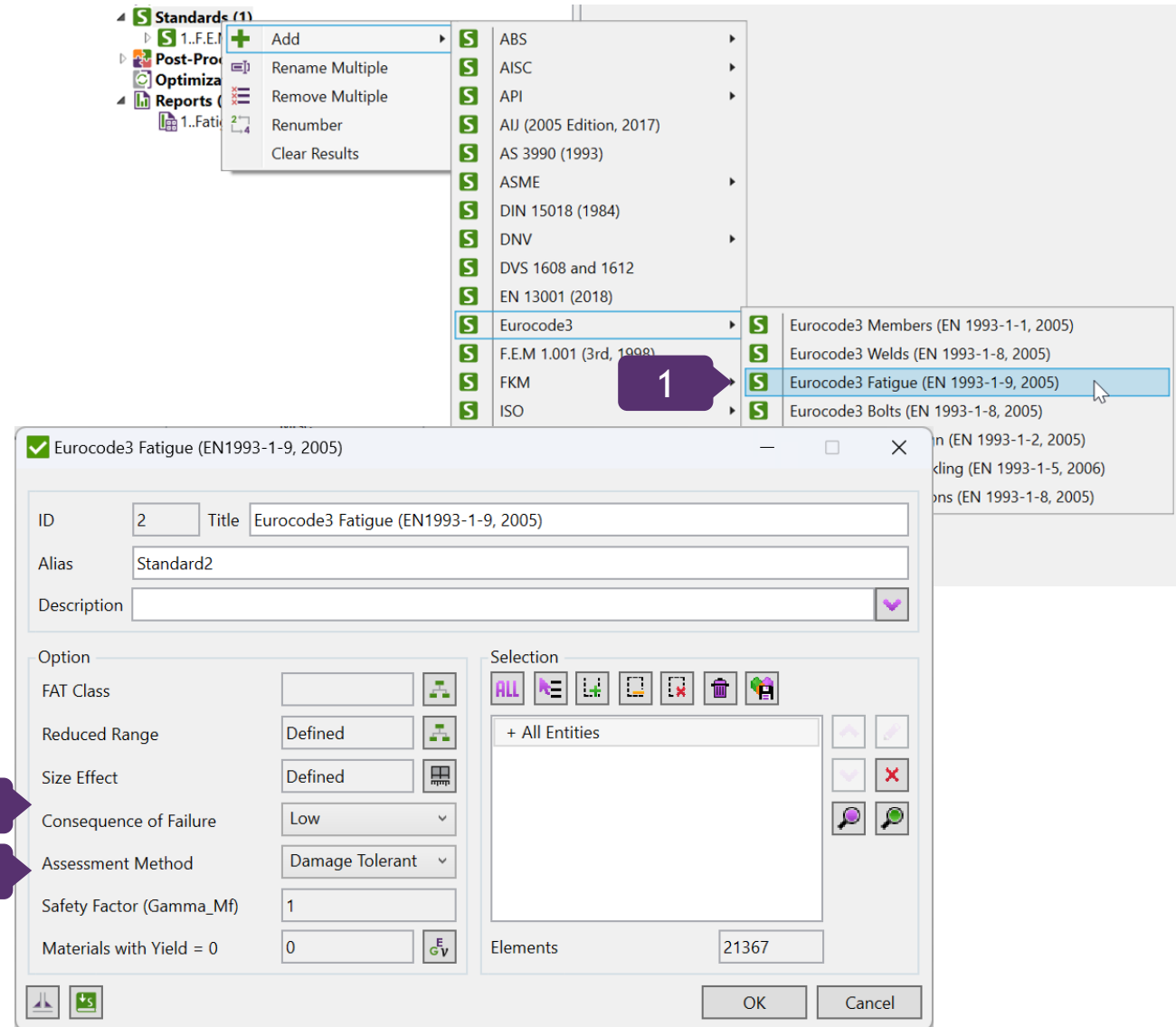
3

Assessment Method: **Damage tolerant**

Safety Factor	Low consequence	High consequence
Damage tolerant	1.0	1.15
Safe life	1.15	1.35

2

3




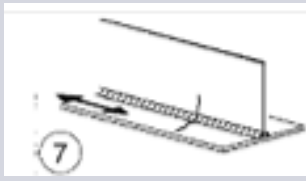
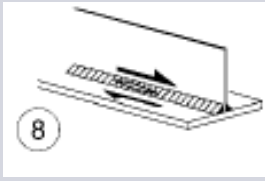




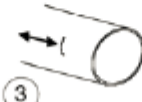
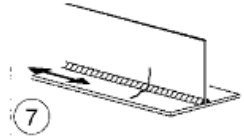
	Perpendicular to weld	Parallel with weld	Shear
Weld	80 	100 	80 
No weld	160 		100 

Table 8.1: Plain members and mechanically fastened joints

Detail category	Constructional detail	Description	Requirements
160	<p>NOTE The fatigue strength curve associated with category 160 is the highest. No detail can reach a better fatigue strength at any number of cycles.</p>   	<p><u>Rolled and extruded products:</u></p> <p>1) Plates and flats; 2) Rolled sections; 3) Seamless hollow sections, either rectangular or circular.</p>	<p><u>Details 1) to 3):</u></p> <p>Sharp edges, surface and rolling flaws to be improved by grinding until removed and smooth transition achieved.</p>
100		<p>7) Repaired automatic or manual fillet or butt welds for categories 1) to 6).</p>	<p>7) Improvement by grinding performed by specialist to remove all visible signs and adequate verification can restore the original category.</p>

For determination of FAT classes check standard!
In this tutorial only examples are given

1 Press Define for the FAT Class.

2 Full Model: **160**

3 All Entities: **100** (No weld)

4 For welds: X: **100**; Y/XY: **80**

5 For welds intersections: X: **80**

Edit Classification

ID: 1 Title: FAT Class

Alias: FAT

Description: [dropdown arrow]

Element(s) Classification

FAT Stress: 160 [dropdown arrow] [Apply]

Direction: X [dropdown arrow] [Apply]

Selection	Classification
Full Model	160
All Entities	100 (XY, YZ, ZX)
All welds	100 (X)
All welds	80 (Y, XY)
All welds intersections	80 (X)

[Import Welds] [Clear] [OK] [Cancel]

✓ Edit Classification

ID1TitleFAT Class

AliasFAT

Description

Element(s) Classification

FAT Stress160Apply

DirectionXApply

Selection	Classification
Full Model	160
All Entities	100 (XY, YZ, ZX)
All welds	100 (X)
All welds	80 (Y, XY)
All welds intersections	80 (X)

Import Welds

Clear

OK

Cancel

Number IDs

Fatigue (EN1993-1-9, 2005)

Selection

ALL

+ All Entities

Elements

Values

Labels

Selection

X

Y

Z

XY

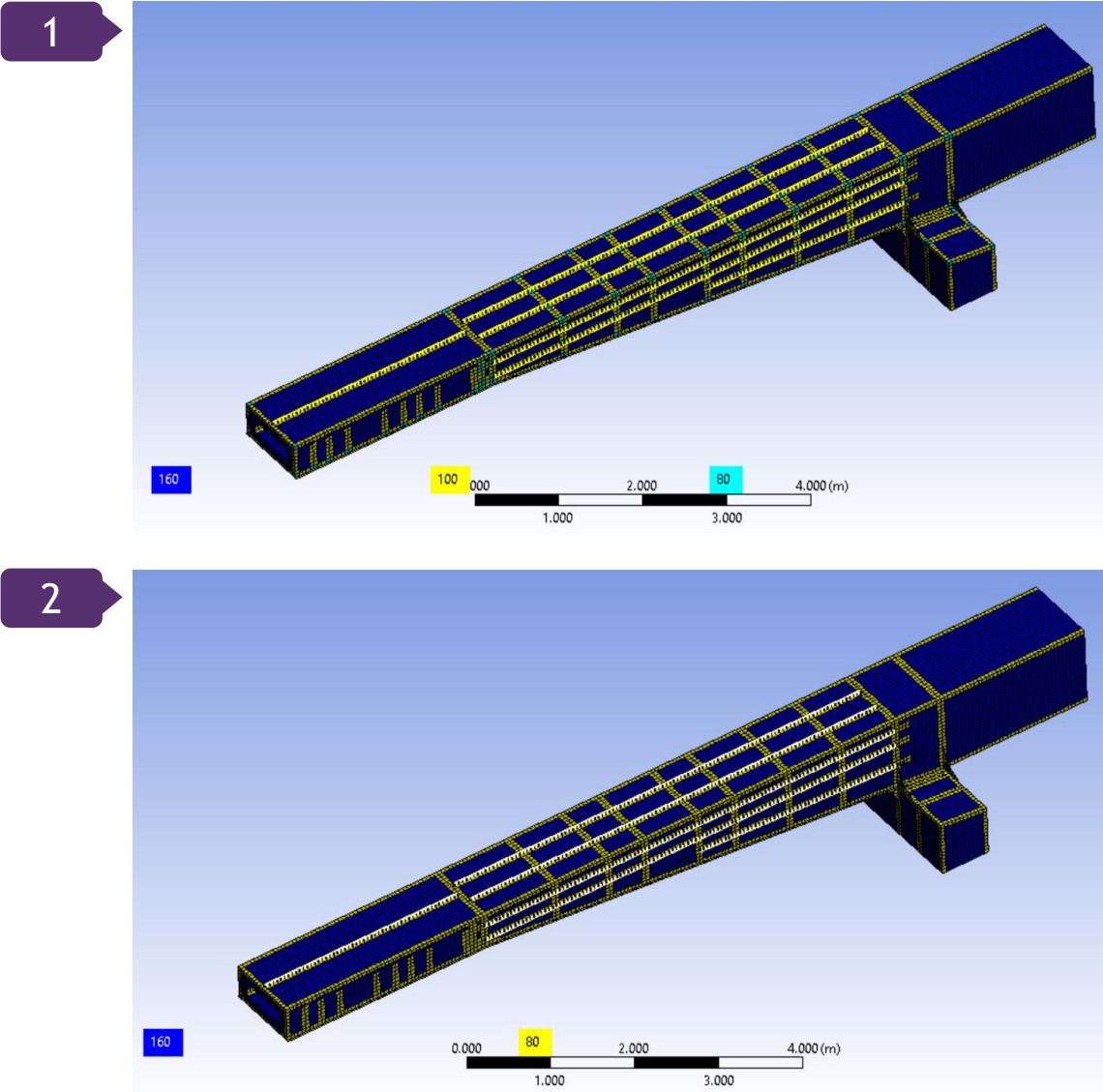
YZ

ZX

Equivalent

1

2



Fatigue Damage Plot

1

Execute *Criteria Plot* in **Fatigue Check** context menu

2

Parameter: **Summed Damage**

3

Direction: **Overall**

4

Point of interest: **Total** Type: **AbsMax**

5

Press  *Preview*

6

Press *OK*

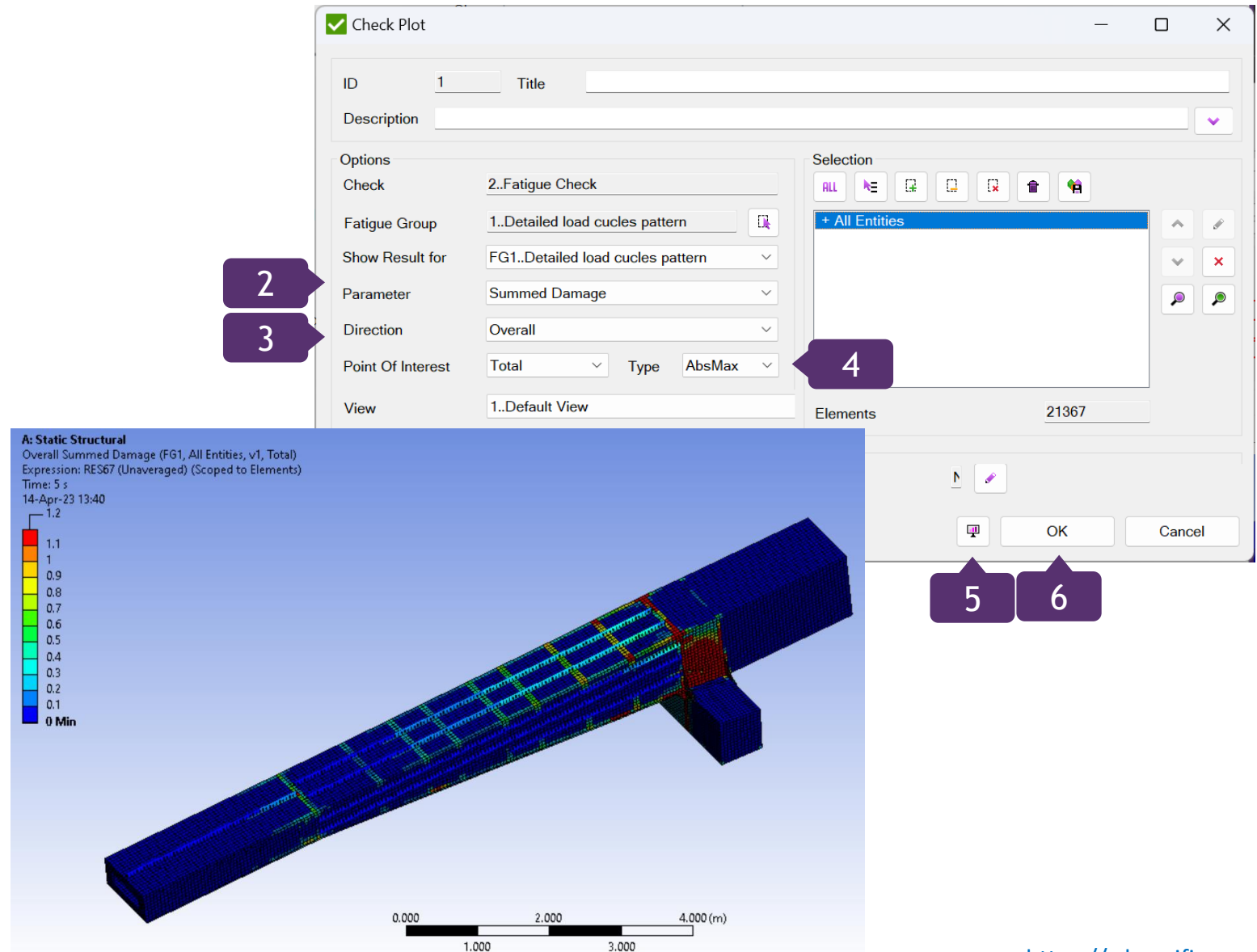
2

3

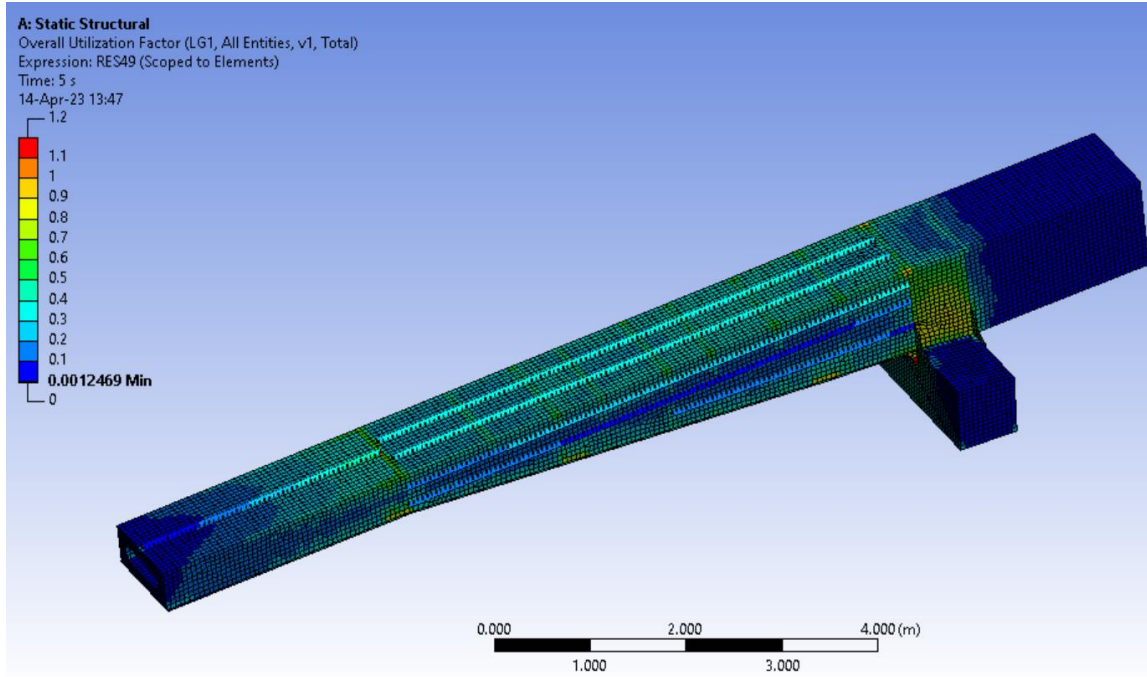
4

5

6



FEM 1.001 utilization factor



Eurocode 3 utilization factor at 2 million cycles

