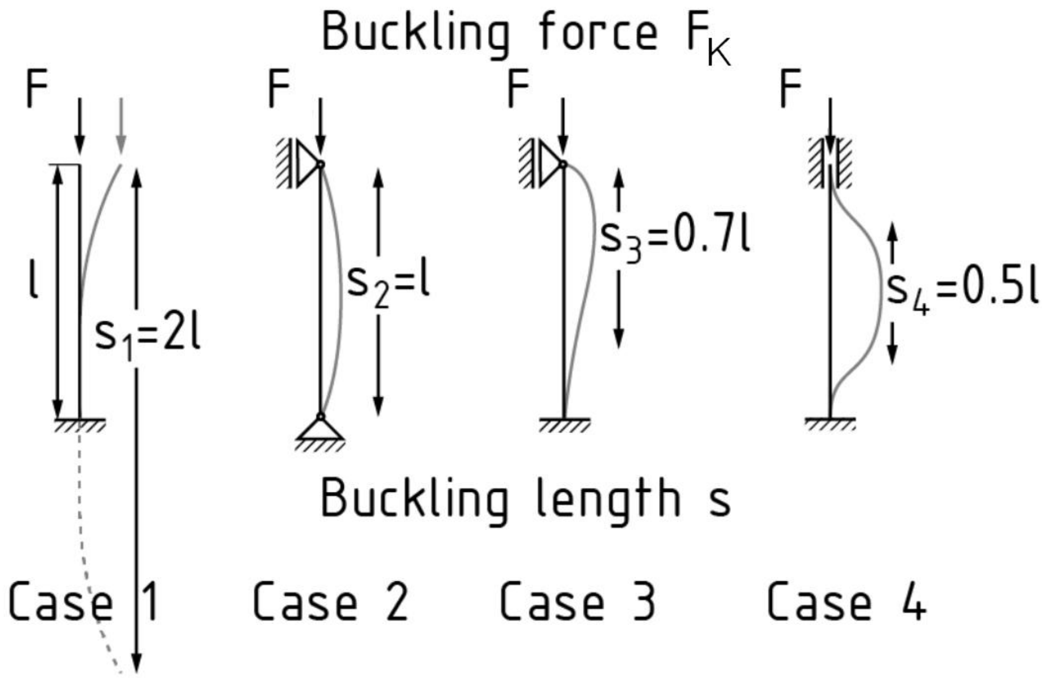
Part 4: Buckling-Analysis with FEM-System MEANS V11

Euler Cases

For 4 typical cases, the critical load and can be calculated using the Euler Load Cases.Typical buckling problems occur with pressure loaded bars or buckling of thin sheets, plates or shells.



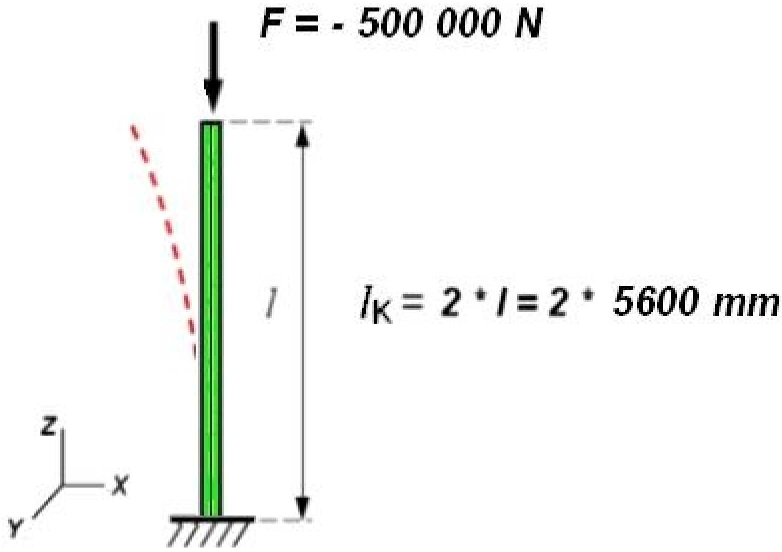
- Case 1: clamped/free - $\beta = 2$: $s_1 = 2 \cdot L$:
- Case 2: articulated/articulated - $\beta = 1$: $s_2 = 1 \cdot L$
- Case 3: clamped/articulated - $\beta = 0.699$: $s_3 = 0.699 \cdot L$
- Case 4: clamped/clamped - $\beta = 0.5$: $s_4 = 0.5 \cdot L$

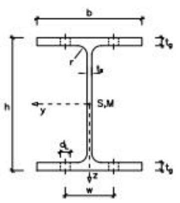
$$F_K = \frac{\pi^2 EI}{l_K^{\,2}}$$

F_k is the Critical Buckling Load und **l_k** is the effective length of the column.

Euler Case 1:

The same cantilevered IPB beam with a HE-B300 profile according to DIN 1025 with a length of 5600 mm from the previous chapter 3 is used again. The axial force is 500 kN. How big is the Critical Buckling Load and the Safety Factor for Buckling?





HE-B Profile nach DIN 1025-2, EURONORM 53 - 62

	Abmessungen					Flächen			Biegung um die y-Achse			Biegung um die z-Achse		
Profil	h	b	ts	tg	r	A	Asteg	G	Iy	iy	Wy	Iz	iz	Wz
HE-B	mm	mm	mm	mm	mm	cm^2	cm^2	kg/m	cm^4	mm	cm^3	cm^4	mm	cm^3
100	100.00	100.00	6.00	10.00	12.00	26.00	4.80	20.41	450.00	41.60	89.90	167.00	25.30	33.50
120	120.00	120.00	6.50	11.00	12.00	34.00	6.37	26.69	864.00	50.40	144.00	318.00	30.60	52.90
140	140.00	140.00	7.00	12.00	12.00	43.00	8.12	33.76	1510.00	59.30	216.00	550.00	35.80	78.50
160	160.00	160.00	8.00	13.00	15.00	54.30	10.70	42.63	2490.00	67.80	311.00	889.00	40.50	111.00
180	180.00	180.00	8.50	14.00	15.00	65.30	12.90	51.26	3830.00	76.60	426.00	1360.00	45.70	151.00
200	200.00	200.00	9.00	15.00	18.00	78.10	15.30	61.31	5700.00	85.40	570.00	2000.00	50.70	200.00
220	220.00	220.00	9.50	16.00	18.00	91.00	17.90	71.44	8090.00	94.30	736.00	2840.00	55.90	258.00
240	240.00	240.00	10.00	17.00	21.00	106.00	20.60	83.21	11260.00	103.00	938.00	3920.00	60.80	327.00
260	260.00	260.00	10.00	17.50	24.00	118.00	22.50	92.63	14920.00	112.00	1150.00	5130.00	65.80	395.00
280	280.00	280.00	10.50	18.00	24.00	131.00	25.60	102.84	19270.00	121.00	1380.00	6590.00	70.90	471.00
300	300.00	300.00	11.00	19.00	27.00	149.00	28.80	116.97	25170.00	130.00	1680.00	8560.00	75.80	571.00
320	320.00	300.00	11.50	20.50	27.00	161.00	32.10	126.39	30820.00	138.00	1930.00	9240.00	75.70	616.00
340	340.00	300.00	12.00	21.50	27.00	171.00	35.60	134.24	36660.00	146.00	2160.00	9690.00	75.30	646.00
360	360.00	300.00	12.50	22.50	27.00	181.00	39.40	142.09	43190.00	155.00	2400.00	10140.00	74.90	676.00
400	400.00	300.00	13.50	24.00	27.00	198.00	47.50	155.43	57680.00	171.00	2880.00	10820.00	74.00	721.00
450	450.00	300.00	14.00	26.00	27.00	218.00	55.70	171.13	79890.00	191.00	3550.00	11720.00	73.30	781.00
500	500.00	300.00	14.50	28.00	27.00	239.00	64.40	187.62	107200.00	212.00	4290.00	12620.00	72.70	842.00
550	550.00	300.00	15.00	29.00	27.00	254.00	73.80	199.39	136700.00	232.00	4970.00	13080.00	71.70	872.00
600	600.00	300.00	15.50	30.00	27.00	270.00	83.70	211.95	171000.00	252.00	5700.00	13530.00	70.80	902.00
650	650.00	300.00	16.00	31.00	27.00	286.00	94.10	224.51	210600.00	271.00	6480.00	13980.00	69.90	932.00
700	700.00	300.00	17.00	32.00	27.00	306.00	108.00	240.21	256900.00	290.00	7340.00	14440.00	68.70	963.00
800	800.00	300.00	17.50	33.00	30.00	334.00	128.00	262.19	359100.00	328.00	8980.00	14900.00	66.80	994.00
900	900.00	300.00	18.50	35.00	30.00	371.00	154.00	291.24	494100.00	365.00	10980.00	15820.00	65.30	1050.00
1000	1000.00	300.00	19.00	36.00	30.00	400.00	176.00	314.00	644700.00	401.00	12890.00	16280.00	63.80	1090.00

Calculaion of the Critical Buckling Load and Safety Factor according Euler Case 1:

E = 210 000 N/mm^2
I_z = 8 560 cm^4
l_k = 2 * 5 600 mm
t_g = 19 mm and t_s = 17 mm

Critical Buckling Load

Fk = 3.141 * 3.141 * 210 000 N/mm^2 * 8 560 * 10 000 mm^4 / 4 * 5600 * 5600 mm^2

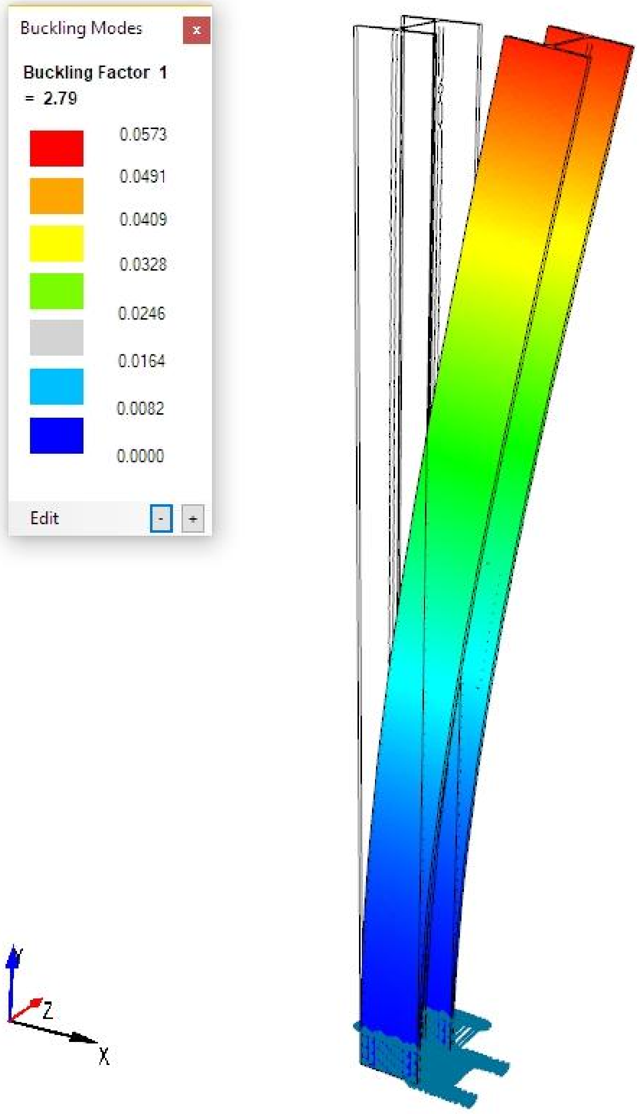
Fk = 1 413 816 N

Safety Factor for Buckling

$S_k = F_k / F$ = 1 413 816 N / 500 000 N = **2.823**

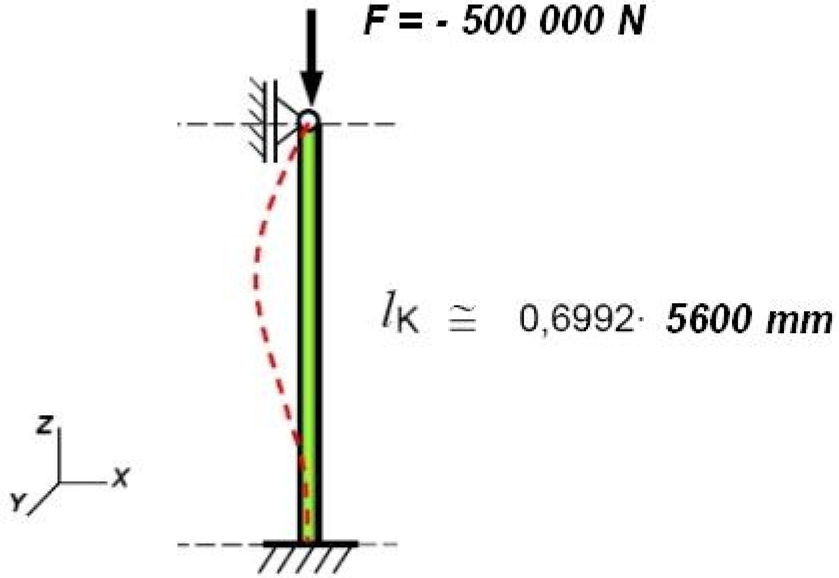
Safety Factor for Buckling calculate with FEM-System MEANS V11

Buckling Factor S_k = 2.79



Euler Case 3:

This IPE Profile is additionally clamped in X and Y directions according to Euler Case 3. How big is the Critical Buckling Load and the Safety Factor?



Calculation of the Critical Buckling Load and Safety Factor according Euler Case 3:

E = 210 000 N/mm^2
I_z = 8560 cm^4
l_k = 0.6992 * 5600 mm

Critical Buckling Load

Fk = 9.869 * 210 000 N/mm^2 * 856000000 mm^4 / (0.6992 * 0.6992 * 5600 ^{2} m^2)

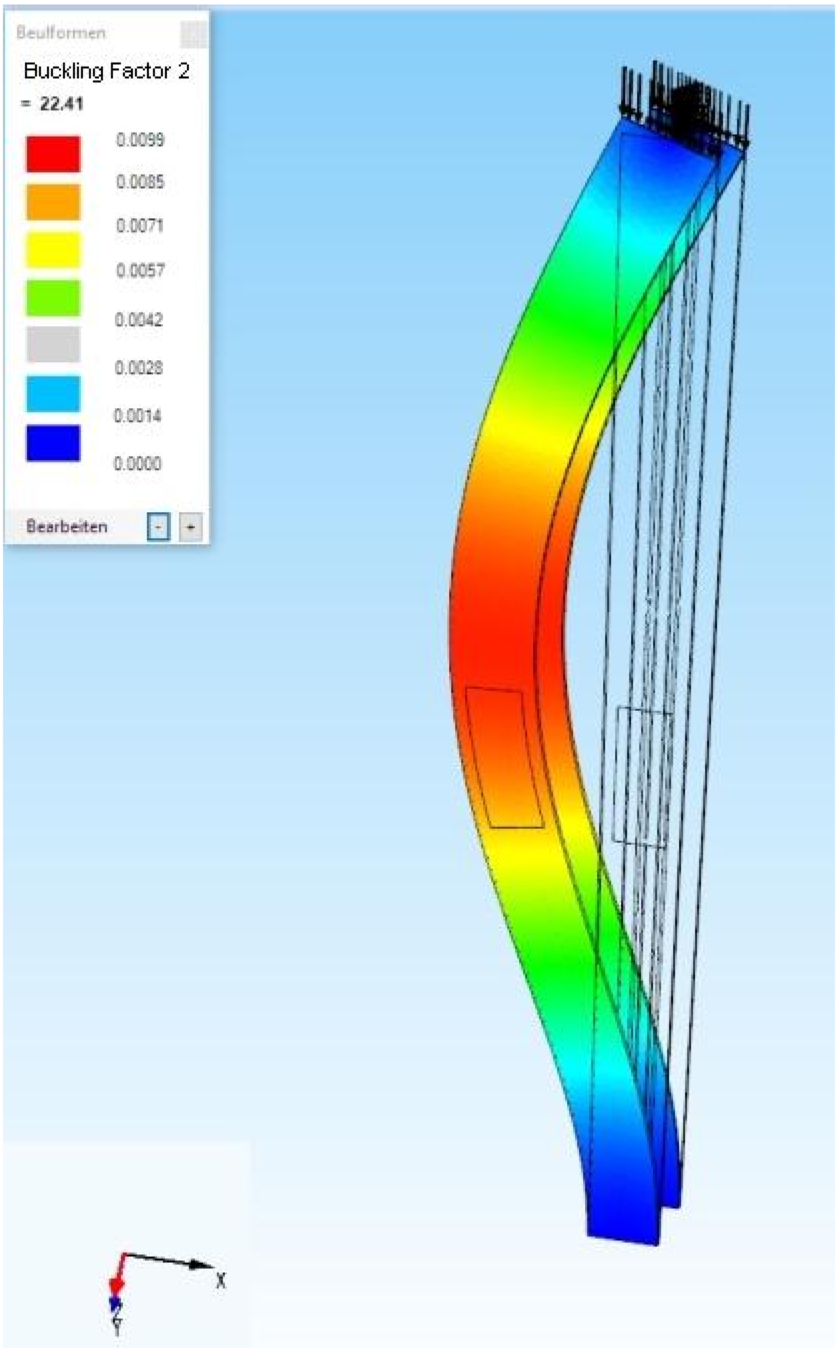
Fk = 11 571 437.5 N

Safety Factor for Buckling

$S_k = F_k / F$ = 11 571 437.5 N / 500 000 N = **23.14**

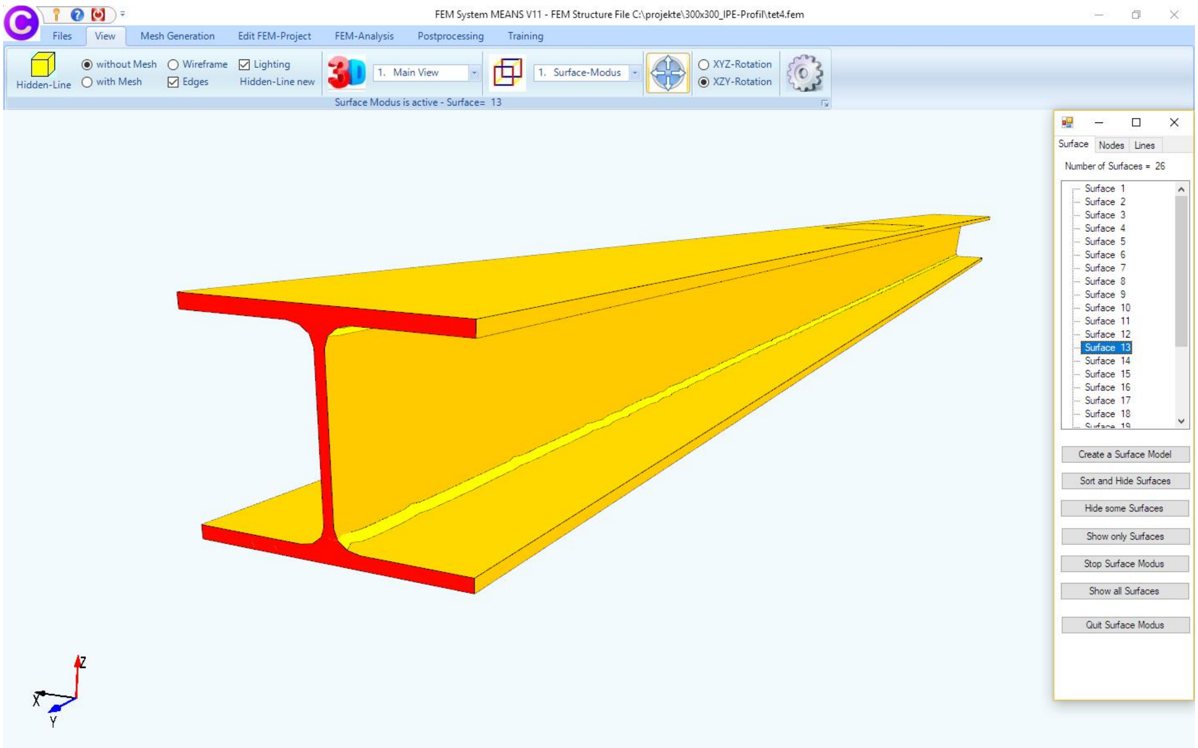
Safety Factor for Buckling calculate with FEM-System MEANS V11 and a Tetrahedral Model:

Buckling Factor S_k = 22.41

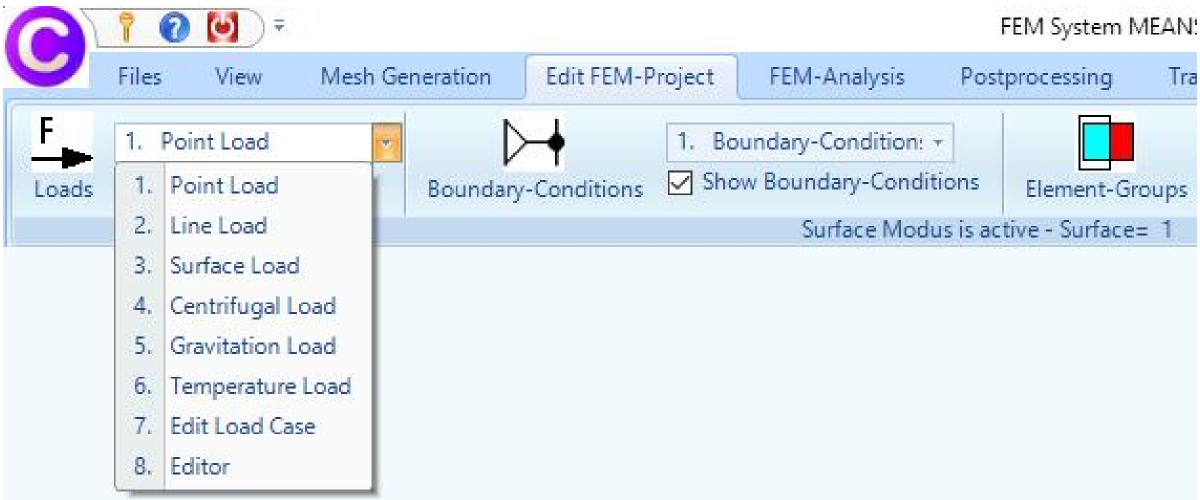


Load Case 1

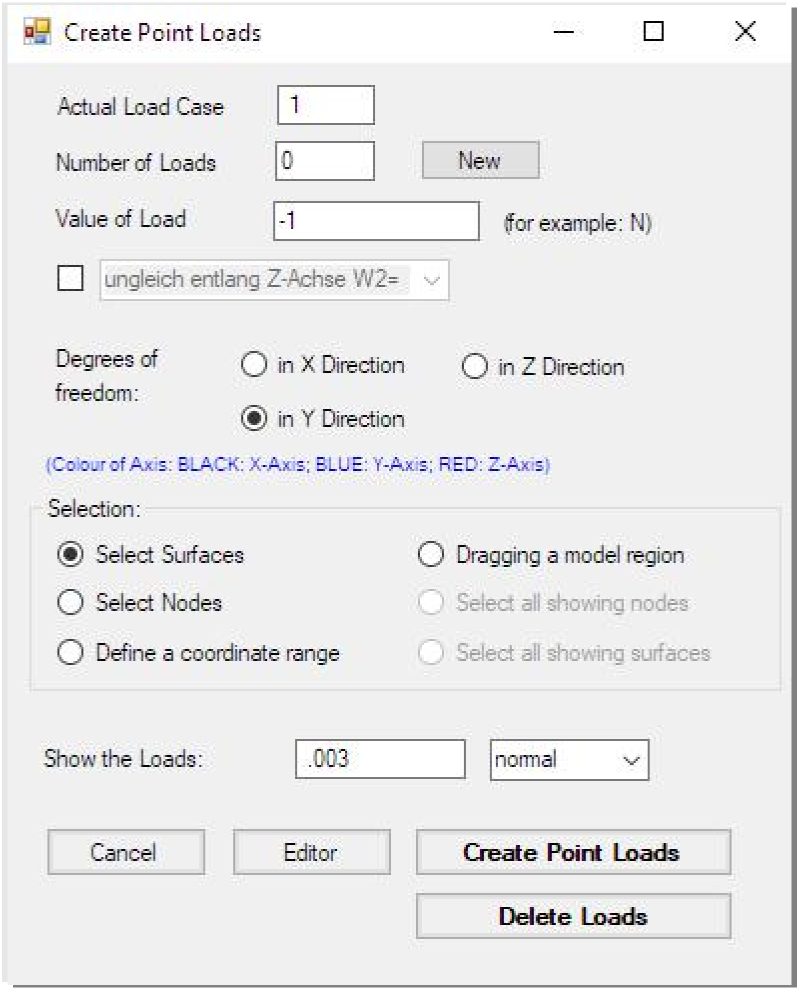
Now rotate the model with the left and right mouse button (only for DX9) around the Z axis into the following view so that the front Surface 13 can be loaded in the Z direction and the rear Surface 10 can be clamped.



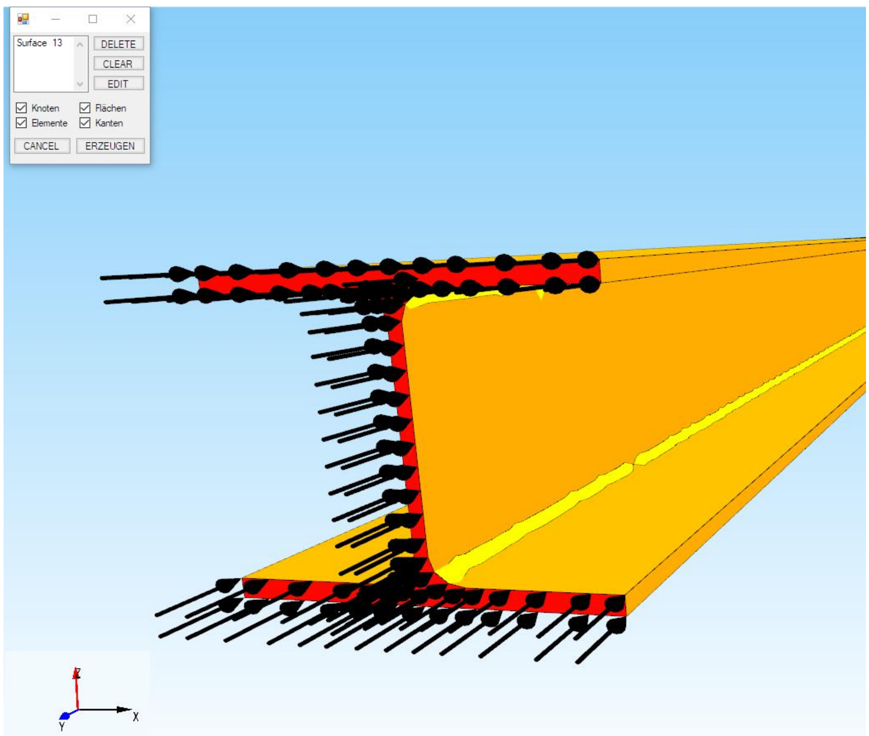
Select the „Edit FEM Project“ tab and the drop-down menu "1. Point Load " to enter Load Case 1.



In the next dialog box, enter Load Case 1 with the pro forma value "-1" because the number of nodes in area 13 is not yet known as well as the degree of freedom "in Y direction" with the selection "Surface " and click on the button "Create Point Load".

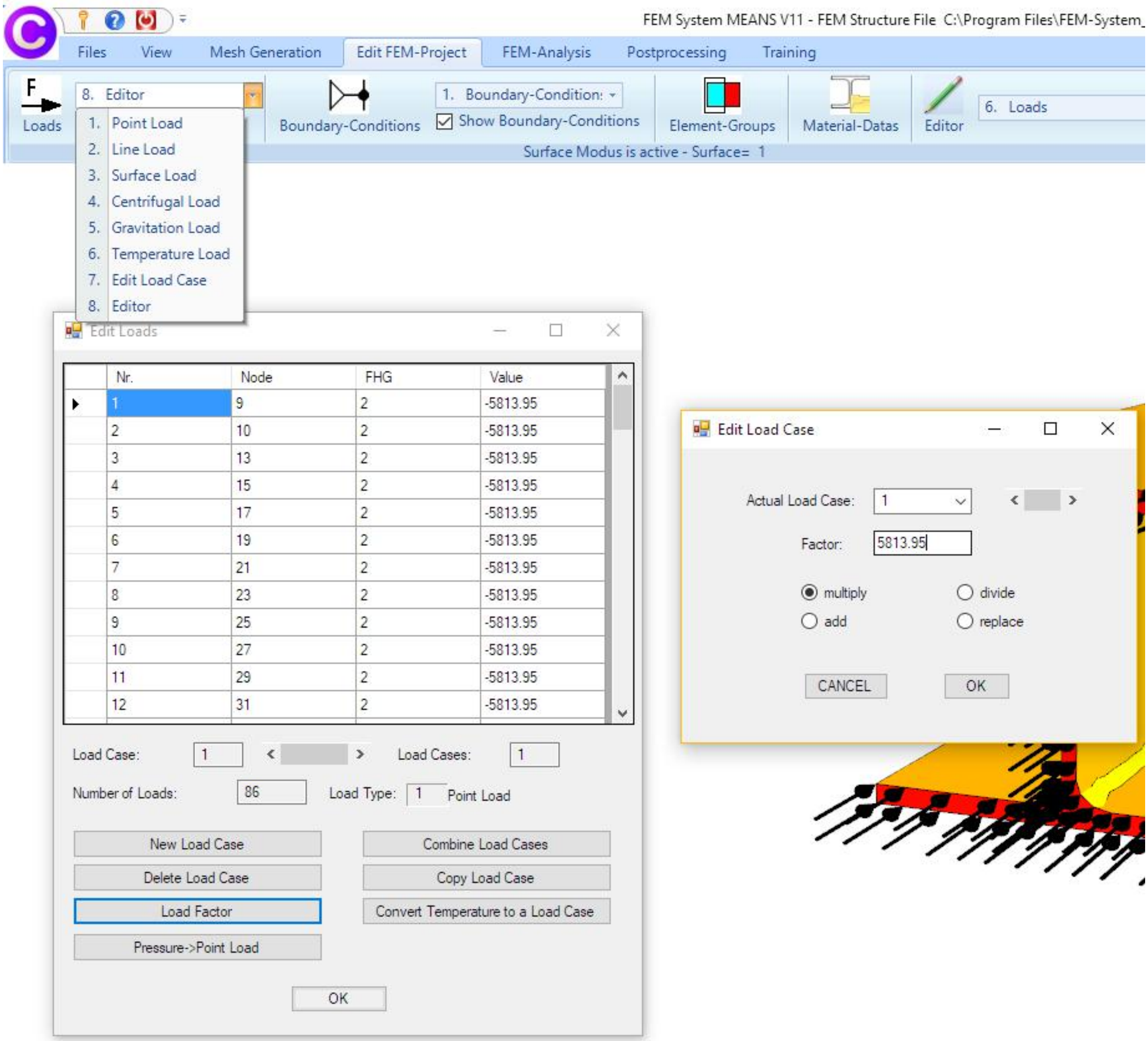


Now create the Load with a Double-click on the Surface 13. This is displayed in the ‘Select box and must be created there with "Create" as a Point Load with 86 nodes.



Enter the load value

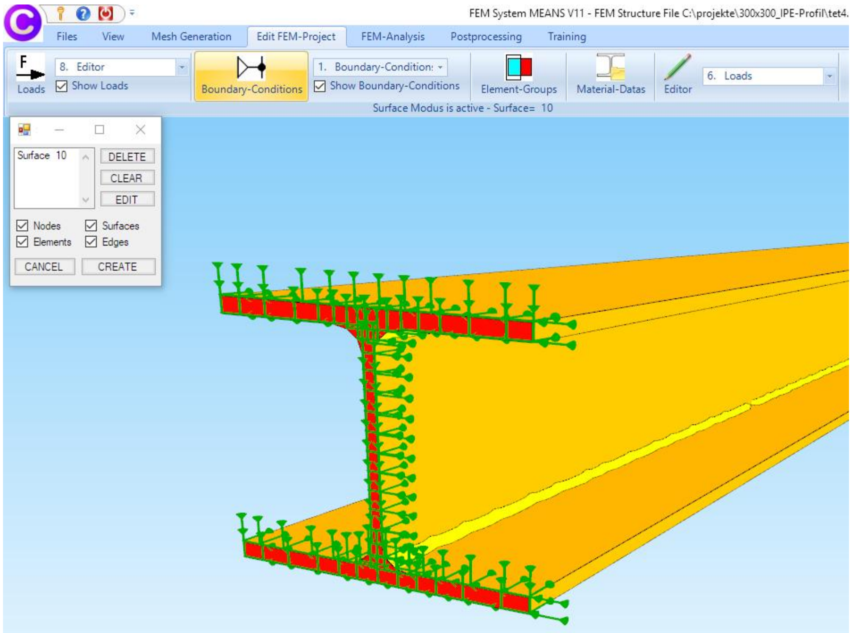
A point load with 86 node forces and the load value -1 has now been generated. Now multiply with menu "8. Editor " and „Load Factor" the loads with the value 500 000 / 86 = 5813.95.



Nr.	Node	FHG	Value
1	9	2	-5813.95
2	10	2	-5813.95
3	13	2	-5813.95
4	15	2	-5813.95
5	17	2	-5813.95
6	19	2	-5813.95
7	21	2	-5813.95
8	23	2	-5813.95
9	25	2	-5813.95
10	27	2	-5813.95
11	29	2	-5813.95
12	31	2	-5813.95

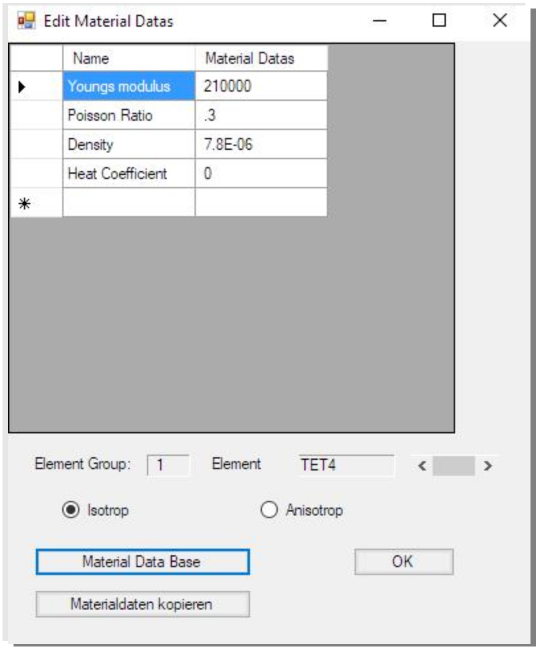
Create Boundary Conditions

Rotate to the rear view with the left and right mouse button (only for DX9) around the Z axis to clamped Surface 10. To clamp the model, select the "Edit FEM Project" tab and click on "Boundary- Conditions". Select "Clamped fixed" and the Selection "Select Surfaces" and choose the "Create RBs" button and double-click on the Surface 10 and enter in the Selectbox with "Create".



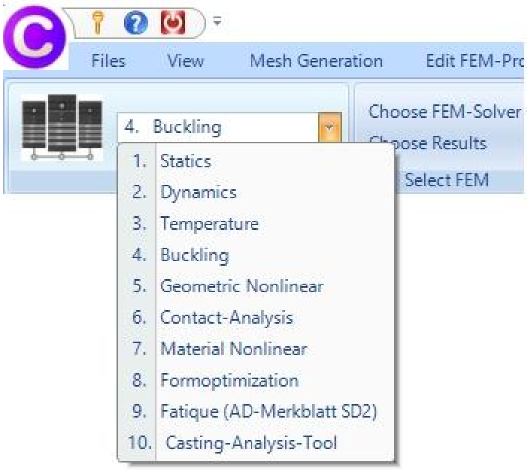
Create Material Datas

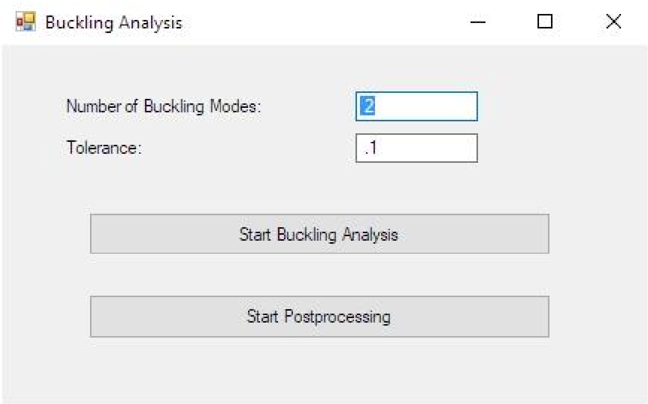
Select the "Edit FEM Project" tab and the icon  to enter the material data such as Young's modulus and Poisson Ratio where steel is always preset.



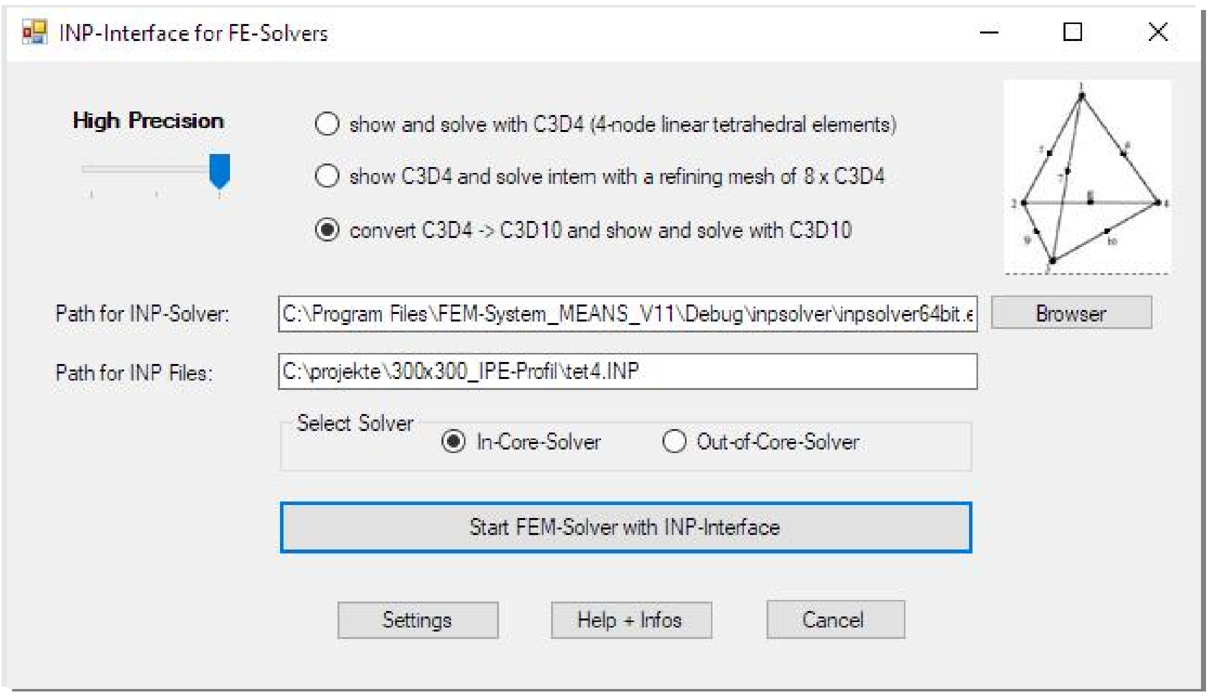
Buckling-Analysis

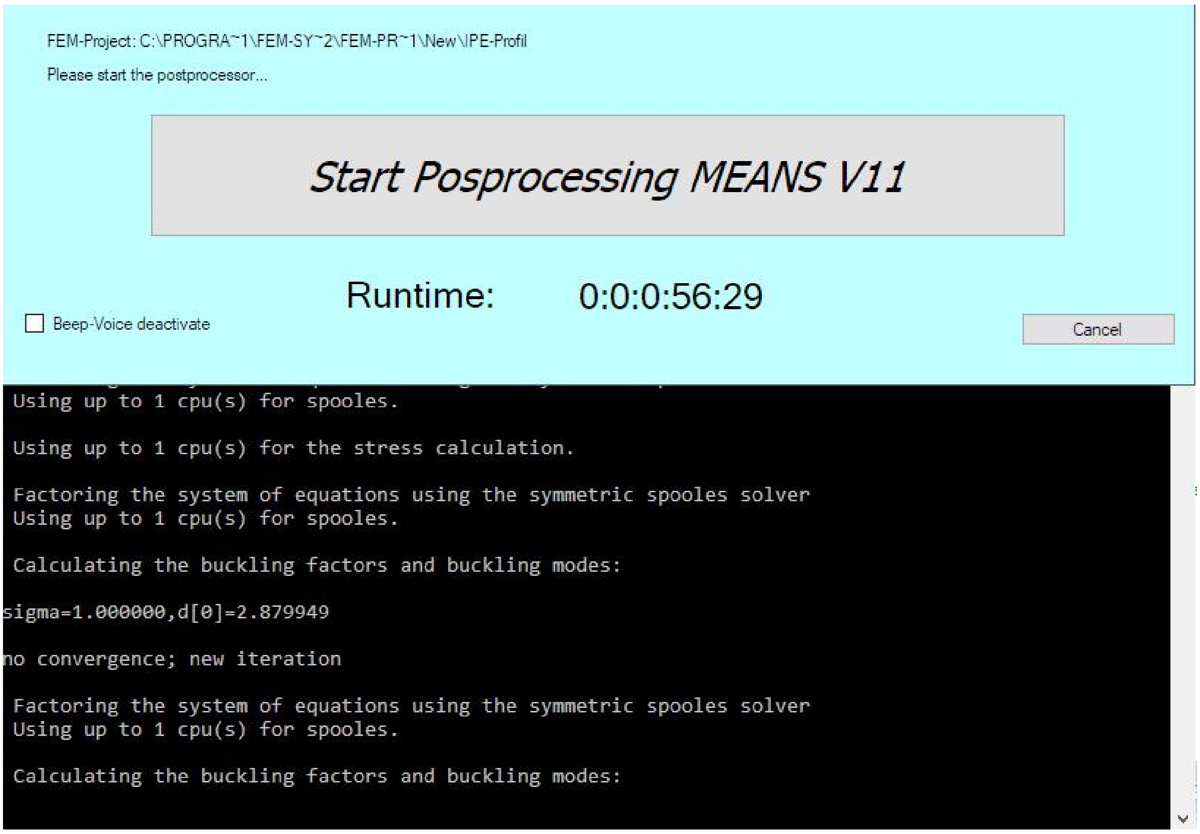
Select „FEM-Analysis“ tab and menu „4. Buckling“ to calculate the Critical Buckling Load and the the Safety Factor for Buckling with the Quick-Solver for 2 Buckling-Modes.





Select the Quick-Solver menu „convert C3D4->C3D10 ...“ to calculate with the high precision tetrahedral elements TET10.

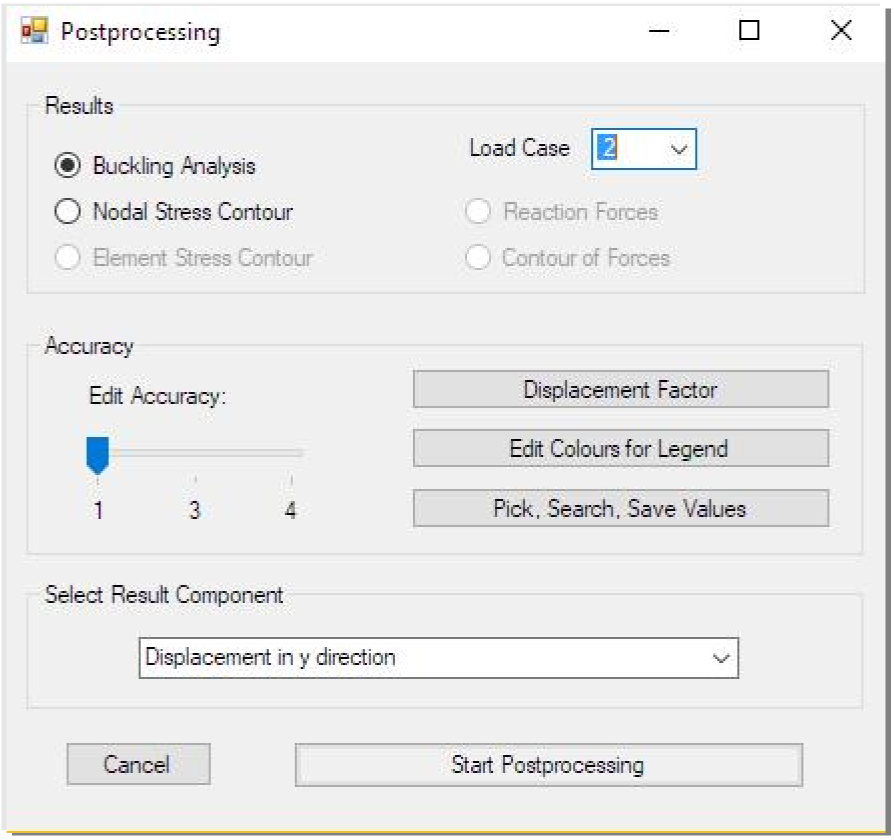




After the FEM Analysis you can start the Postprocessor with menu „Start Postprocessing MEANS V11“ for the result evaluation.

Postprocessing

Select the tab "Postprocessing" and click on the Icon  to start the Postprocessor for the result evaluation automatically.



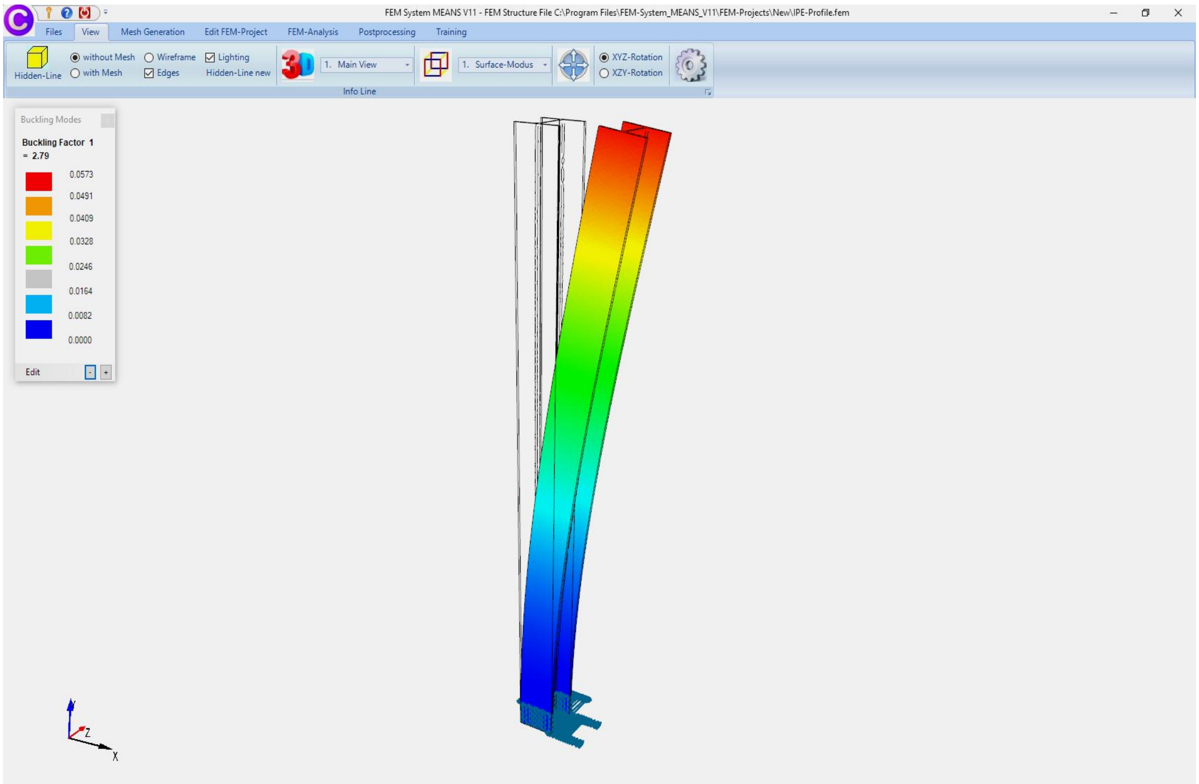
Now 3 Load Cases available for buckling result evaluation:

Load Case 1 with linear Static according Euler Case 1

Load Case 2 with Buckling-Factor 1 according Euler Case 1

Load Case 3 with Buckling Factor 2 according Euler Case 1

Displacements in X-, Y- and Z-Direction with Buckling Factor No. 1 = 2.79



v.Mises-Stresses