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PRODUCT INFORMATION

BACKGROUND

Pursuing the commitment of Lysaght to constant improvement, this edition of LYSAGHT® Zeds and Cees Users Guide reflects the move to limit state design principles.

Since 1987, in conjunction with the University of Sydney, we have intensively researched the behaviour of purlin and girt systems using the vacuum test rig at the University, which is the only one of its type in Australia and the largest in the world. In our NATA-registered laboratory we have tested full-scale purlin and girt systems on single, double and lapped continuous configurations for both inward and outward loading.

It has been possible to gain a sound understanding of their behaviour. This knowledge allows us to remain at the forefront of technology, in Australia and overseas.

Since the last edition of this manual, the results of this research has been used in the development of AS/NZS 4600.

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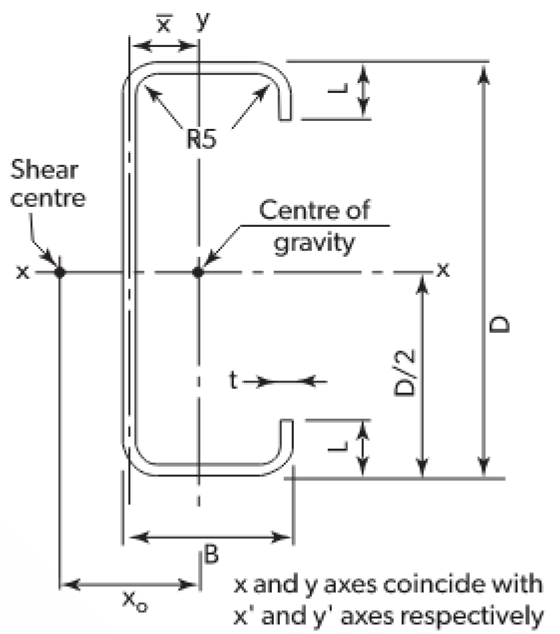
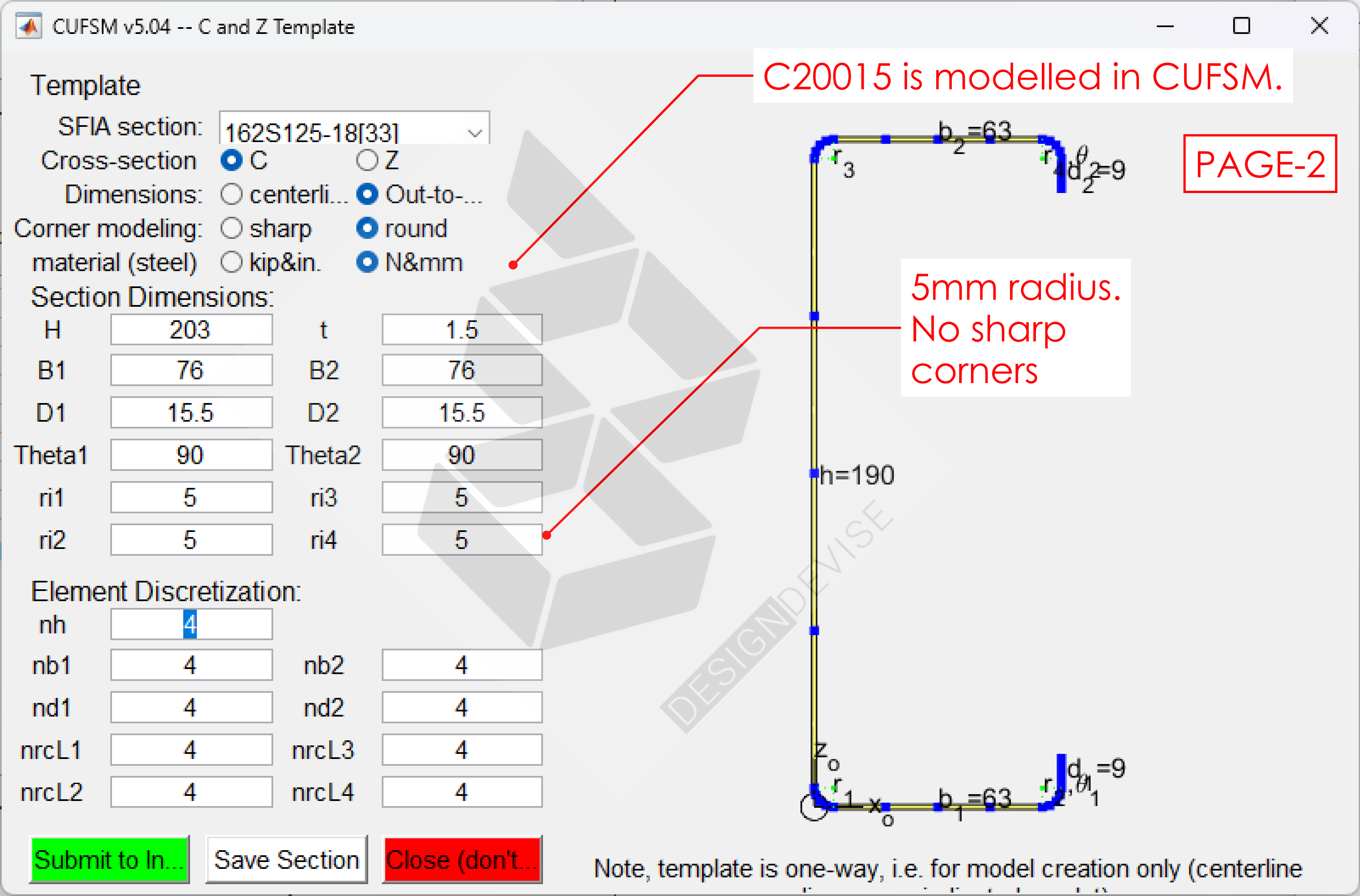
Cee section

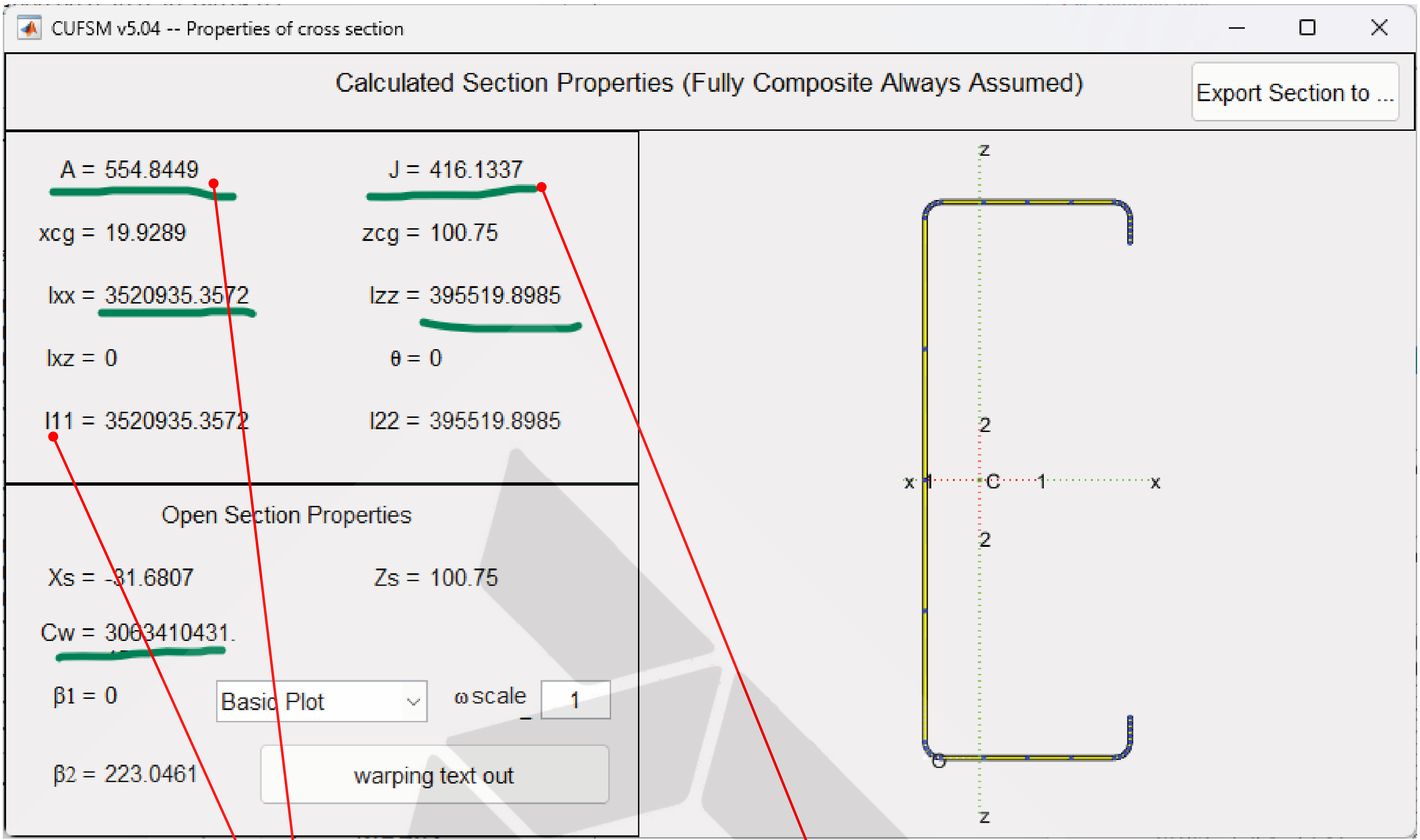


Lysaght C20015 example. Simply supported 4.8m span. No bridging.

DIMENSIONS OF ZEDS & CEES

Catalogue number	t mm	D mm	Mass per unit length kg/m	Zeds E mm	Zeds F mm	Zeds L mm	Cees B mm	Cees L mm
Z/C10010	1.0	102	1.78	53	49	12.5	51	12.5
Z/C10012	1.2	102	2.10	53	49	12.5	51	12.5
Z/C10015	1.5	102	2.62	53	49	13.5	51	13.5
Z/C10019	1.9	102	3.29	53	49	14.5	51	14.5
Z/C15012	1.2	152	2.89	65	61	15.5	64	14.5
Z/C15015	1.5	152	3.59	65	61	16.5	64	15.5
Z/C15019	1.9	152	4.51	65	61	17.5	64	16.5
Z/C15024	2.4	152	5.70	66	60	19.5	64	18.5
Z/C20015	1.5	203	4.49	79	74	15.0	76	15.5
Z/C20019	1.9	203	5.74	79	74	18.5	76	19.0
Z/C20024	2.4	203	7.24	79	73	21.5	76	21.0
Z/C25019	1.9	254	6.50	79	74	18.0	76	18.5
Z/C25024	2.4	254	8.16	79	73	21.0	76	20.5
Z/C30024	2.4	300	10.09	100	93	27.0	96	27.5
Z/C30030	3.0	300	12.76	100	93	31.0	96	31.5
Z/C35030	3.0	350	15.23	129	121	30.0	125	30.0

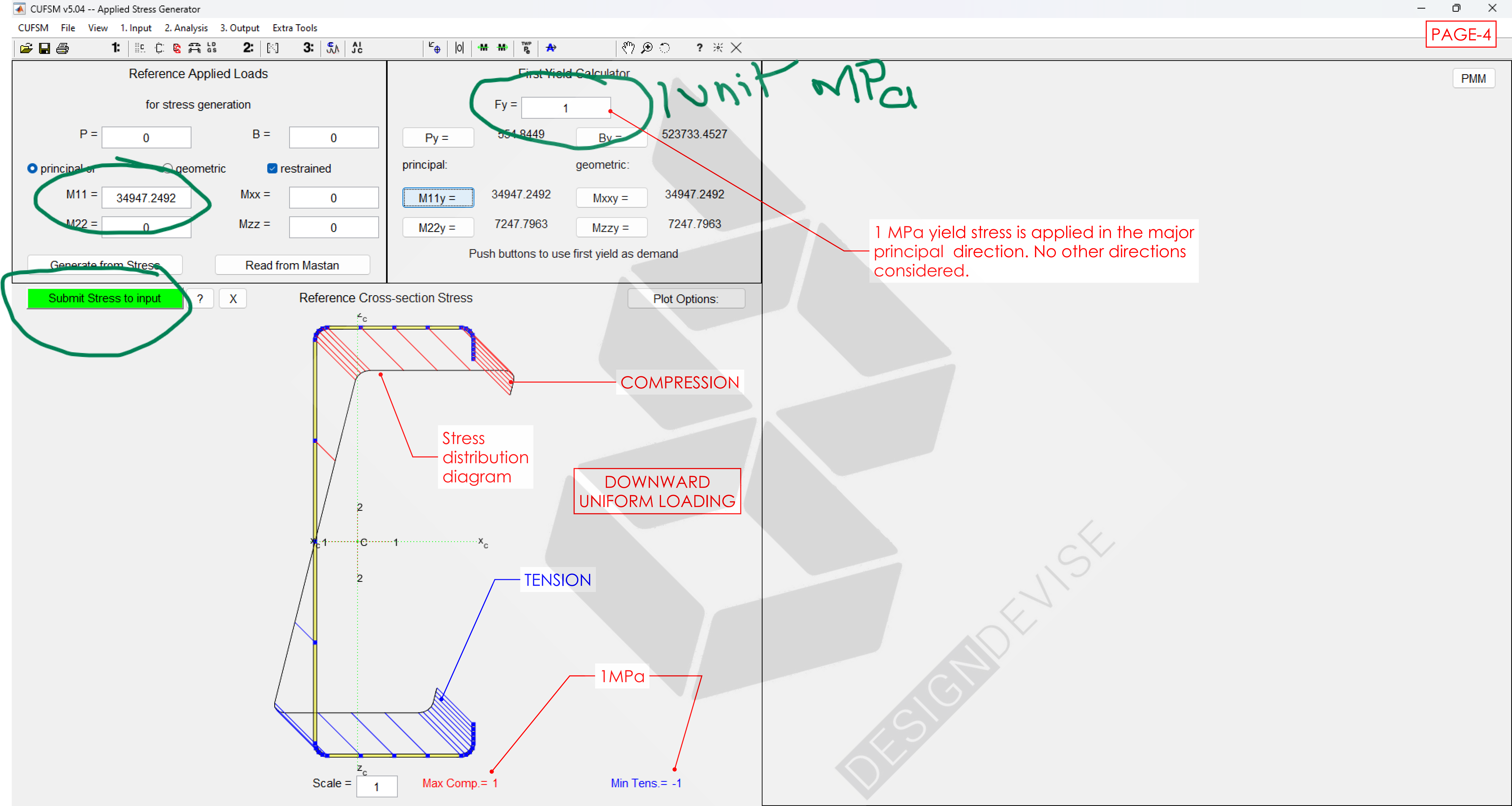

CUFSM v5.04 -- C and Z Template
Template
SFIA section: 162S125-18[33]
Cross-section C Z
Dimensions: centerli... Out-to-...
Corner modeling: sharp round
material (steel) kip&in. N&mm
Section Dimensions:
H 203 t 1.5
B1 76 B2 76
D1 15.5 D2 15.5
Theta1 90 Theta2 90
ri1 5 ri3 5
ri2 5 ri4 5
Element Discretization:
nh 4
nb1 4 nb2 4
nd1 4 nd2 4
nrcL1 4 nrcL3 4
nrcL2 4 nrcL4 4
Submit to In...
Save Section
Close (don't...
C20015 is modelled in CUFSM.
PAGE-2
5mm radius.
No sharp
corners
b2=63
h=190
b1=63
d2=9
d1=9
DESIGNDEVISE
Note, template is one-way, i.e. for model creation only (centerline



Modelled section properties are similar to Lysaght actual properties

LYSAGHT® CEES

Product Code	Area	Full Section Properties						Column Properties					Effective Section Properties At Yield Stress	
		Second Moment Of Area		Section Modulus		Radius Of Gyration		Centroid	Shear Centre	Torsion Constant	Warping Constant	Monosymmetry Section Constant	Section Modulus In Bending	Area In Compression
	A mm²	Ix 10⁶mm⁴	Iy 10⁶mm⁴	Zx 10³mm³	Zy 10³mm³	rx mm	ry mm	$\bar{x}$ mm	x_o mm	J mm⁴	Iw 10⁶mm⁶	b_y mm	Zxe 10³mm³	Ae mm²
C10010	216	0.364	0.0755	7.13	2.19	41.1	18.7	16.1	39.9	71.9	160	123	5.37	113
C10012	258	0.432	0.0892	8.48	2.59	41.0	18.6	16.0	39.7	124	188	123	6.74	153
C10015	323	0.537	0.112	10.5	3.29	40.8	18.7	16.1	40.1	242	241	122	8.73	217
C10019	409	0.673	0.142	13.2	4.21	40.6	18.7	16.2	40.4	492	311	122	12.3	329
C15012	354	1.29	0.188	17.0	4.17	60.4	23.1	18.3	46.5	170	842	171	11.8	165
C15015	443	1.61	0.237	21.1	5.29	60.2	23.1	18.4	46.9	332	1070	171	17.1	244
C15019	561	2.02	0.300	26.6	6.74	60.0	23.1	18.5	47.1	675	1370	170	21.8	340
C15024	712	2.54	0.386	33.5	8.79	59.8	23.3	18.9	48.0	1370	1810	169	30.9	527
C20015	555	3.53	0.396	34.7	7.7	79.7	26.7	19.9	51.6	416	3060	223	24.1	251
C20019	713	4.51	0.531	44.4	9.77	79.6	27.3	20.8	53.6	858	4240	221	36.6	381
C20024	904	5.69	0.681	56.0	12.7	79.3	27.4	21.1	54.4	1740	5540	219	47.5	541
C25019	808	7.62	0.561	60.0	9.86	97.1	26.4	18.1	48.5	972	6860	276	46.2	381
C25024	1020	9.62	0.721	75.7	12.8	96.9	26.5	18.4	49.3	1970	8920	274	64.9	543



CUFSM v5.04 -- Applied Stress Generator
CUFSM File View 1. Input 2. Analysis 3. Output Extra Tools
PAGE-4
Reference Applied Loads
for stress generation
P = 0
B = 0
principal or geometric
restrained
M11 = 34947.2492
Mxx = 0
M22 = 0
Mzz = 0
Generate from Stress
Read from Mastan
Submit Stress to input
?
X
First Yield Calculator
Fy = 1
Unit MPa
Py = 551.8449
By = 523733.4527
principal:
geometric:
M11y = 34947.2492
Mxxy = 34947.2492
M22y = 7247.7963
Mzzy = 7247.7963
Push buttons to use first yield as demand
PMM
1 MPa yield stress is applied in the major principal direction. No other directions considered.
Reference Cross-section Stress
Plot Options:
COMPRESSION
Stress distribution diagram
DOWNWARD UNIFORM LOADING
TENSION
1MPa
Scale = 1
Max Comp.= 1
Min Tens.= -1
DESIGNDEVISE

CUFSM v5.04 -- Finite Strip Pre-Processor -- Boundary Conditions Input

CUFSM File View 1. Input 2. Analysis 3. Output Extra Tools

Boundary Condition Selection

Solution type: ?

(•) Signature curve (traditional)   ( ) General boundary condition solution

Boundary Conditions: simple-simple (S-S) ?

Number of eigenvalues: 20 ?

Half-wavelengths and Default longitudinal term m=1 ?

Length

4200.00
4220.00
4240.00
4260.00
4280.00
4300.00
4320.00
4340.00
4360.00
4380.00
4400.00
4420.00
4440.00
4460.00
4480.00
4500.00
4520.00
4540.00
4560.00
4580.00
4600.00
4620.00
4640.00
4660.00
4680.00
4700.00
4720.00
4740.00
4760.00
4780.00
4800.00

← 4.8m

Simply supported condition with 4.8m span

Longitudinal Shape Function Viewer

lengths

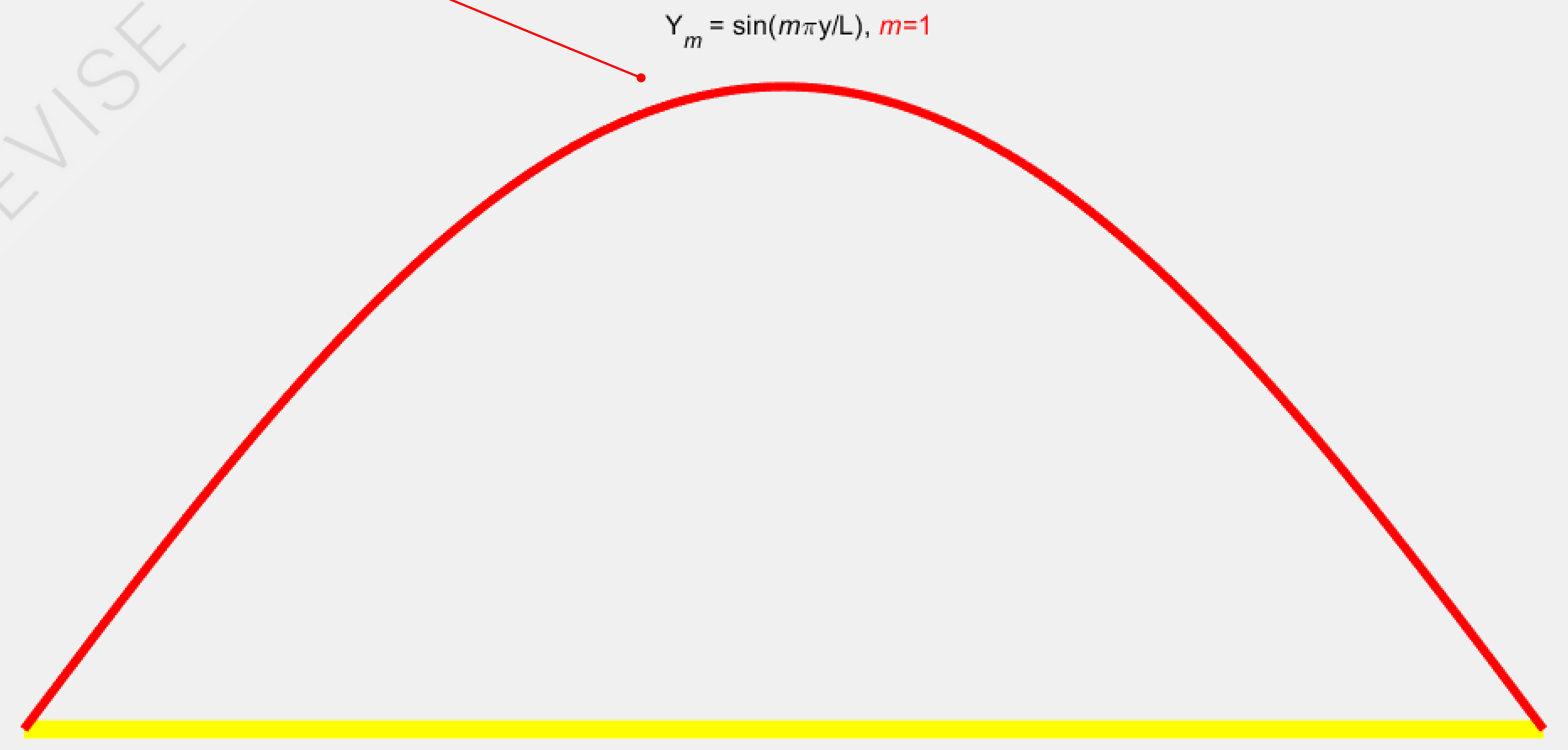
← length = 20 →

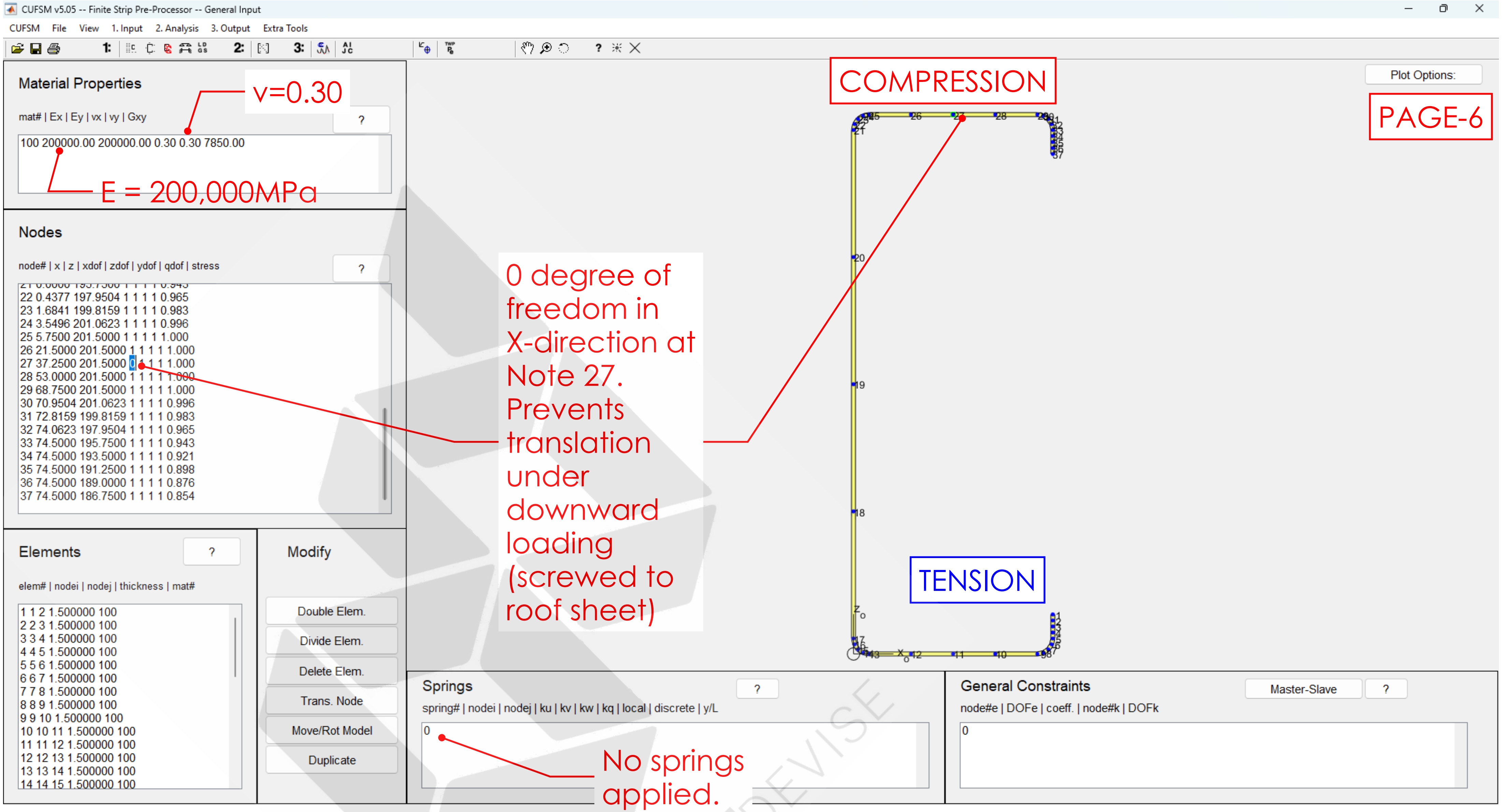
longitudinal terms

1

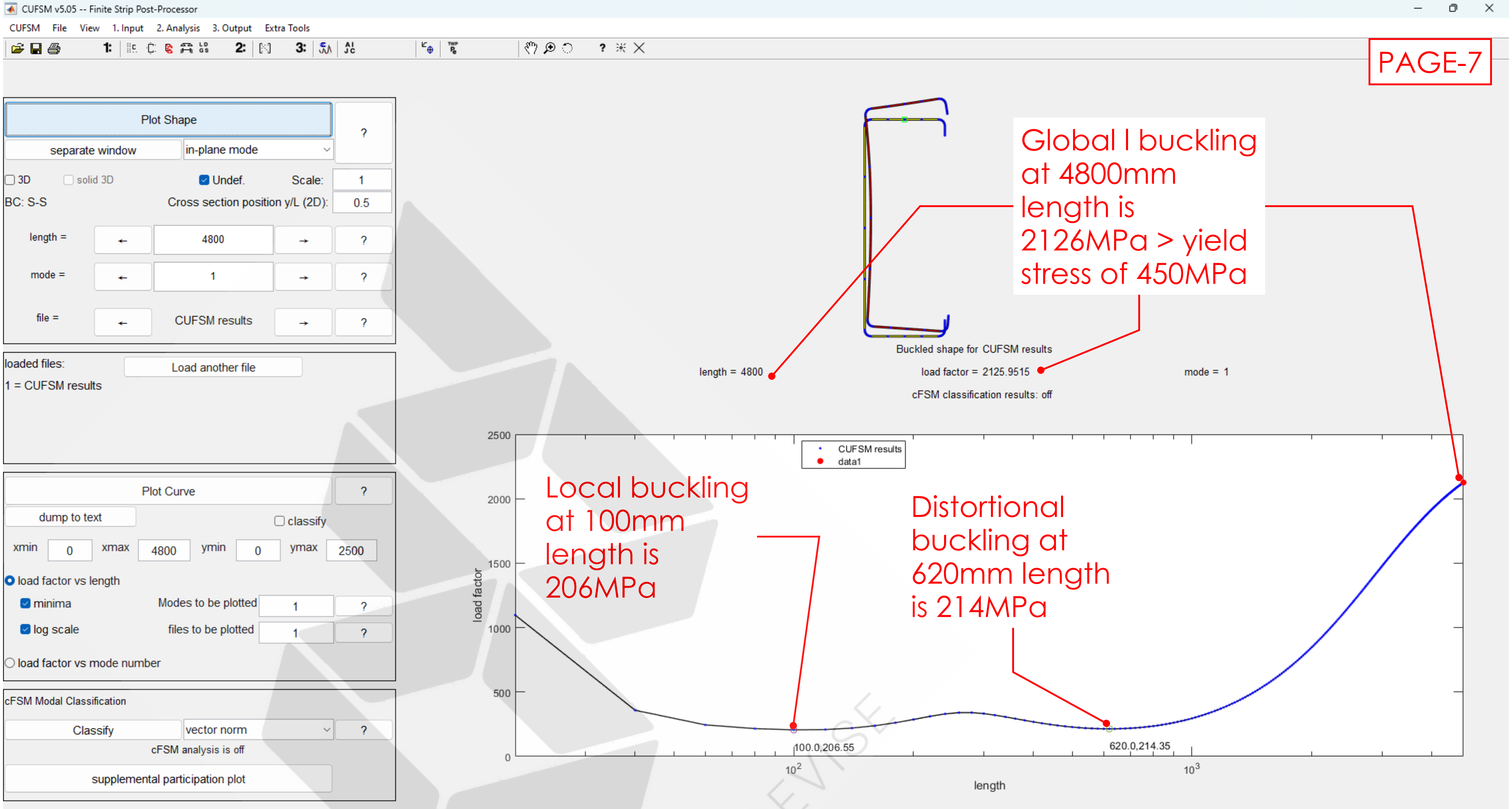
Highlight the shape of selected longitudinal term

← m = 1 →

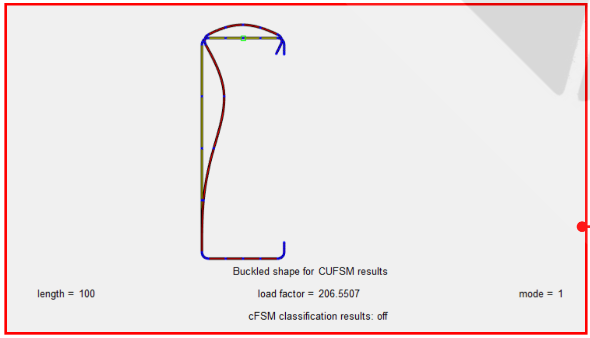




CUFSM v5.05 -- Finite Strip Pre-Processor -- General Input
CUFSM File View 1. Input 2. Analysis 3. Output Extra Tools
Material Properties
mat# | Ex | Ey | vx | vy | Gxy
100 200000.00 200000.00 0.30 0.30 7850.00
v=0.30
E = 200,000MPa
Nodes
node# | x | z | xdof | zdof | ydof | qdof | stress
22 0.4377 197.9504 1 1 1 1 0.965
23 1.6841 199.8159 1 1 1 1 0.983
24 3.5496 201.0623 1 1 1 1 0.996
25 5.7500 201.5000 1 1 1 1 1.000
26 21.5000 201.5000 1 1 1 1 1.000
27 37.2500 201.5000 0 1 1 1 1.000
28 53.0000 201.5000 1 1 1 1 1.000
29 68.7500 201.5000 1 1 1 1 1.000
30 70.9504 201.0623 1 1 1 1 0.996
31 72.8159 199.8159 1 1 1 1 0.983
32 74.0623 197.9504 1 1 1 1 0.965
33 74.5000 195.7500 1 1 1 1 0.943
34 74.5000 193.5000 1 1 1 1 0.921
35 74.5000 191.2500 1 1 1 1 0.898
36 74.5000 189.0000 1 1 1 1 0.876
37 74.5000 186.7500 1 1 1 1 0.854
0 degree of freedom in X-direction at Note 27. Prevents translation under downward loading (screwed to roof sheet)
Elements
elem# | nodei | nodej | thickness | mat#
1 1 2 1.500000 100
2 2 3 1.500000 100
3 3 4 1.500000 100
4 4 5 1.500000 100
5 5 6 1.500000 100
6 6 7 1.500000 100
7 7 8 1.500000 100
8 8 9 1.500000 100
9 9 10 1.500000 100
10 10 11 1.500000 100
11 11 12 1.500000 100
12 12 13 1.500000 100
13 13 14 1.500000 100
14 14 15 1.500000 100
Modify
Double Elem.
Divide Elem.
Delete Elem.
Trans. Node
Move/Rot Model
Duplicate
COMPRESSION
PAGE-6
TENSION
Plot Options:
Springs
spring# | nodei | nodej | ku | kv | kw | kq | local | discrete | y/L
0
No springs applied.
General Constraints
Master-Slave
node#e | DOFe | coeff. | node#k | DOFk
0



Therefore, min. strength is 206MPa (local buckling)



Local buckling at 100mm length 206MPa

Lysaght gives capacities as ultimate udl in kN/m.

Max. downward capacity is 2.88kN/m from the table.

This is equal to 8.29kN.m moment ($wl^2/8$).

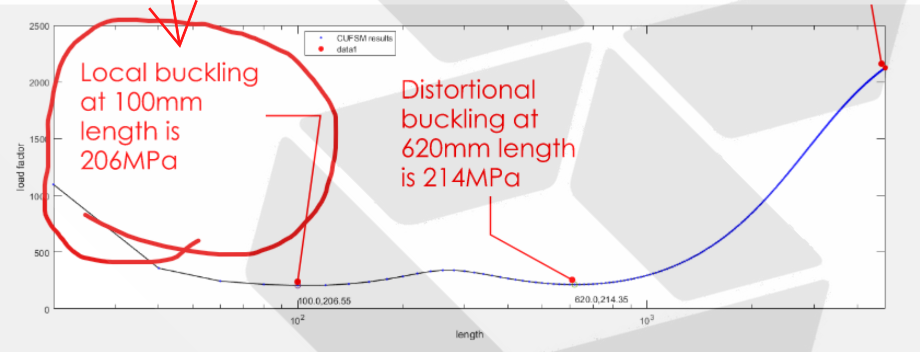
This is equal to bending stress of M/S = 8.29/34.7 = 239MPa

SINGLE SPANS

	Z/C 20015 (kN/m)						
	INWARD		OUTWARD				L/150
Bridging >	0	1, 2, 3	0	1	2	3	
Span mm							
3000	7.38	7.38	7.28	7.38	7.38	7.38	10.60
3300	6.10	6.10	5.47	6.10	6.10	6.10	7.96
3600	5.13	5.13	4.10	5.13	5.13	5.13	6.28
3900	4.33	4.37	3.13	4.37	4.37	4.37	5.07
4200	3.69	3.77	2.44	3.77	3.77	3.77	4.15
4500	3.17	3.28	1.86	3.28	3.28	3.28	3.45
4800	2.75	2.88	1.51	2.88	2.88	2.88	2.88

LYSAGHT® CEES

Product Code	Area	Full Section Properties				
		Second Moment Of Area		Section Modulus		R
	A mm²	Ix 10^6mm^4	Iy 10^6mm^4	Zx 10^3mm^3	Zy 10^3mm^3	r m
C10010	216	0.364	0.0755	7.13	2.19	4
C10012	258	0.432	0.0892	8.48	2.59	4
C10015	323	0.537	0.112	10.5	3.29	4
C10019	409	0.673	0.142	13.2	4.21	4
C15012	354	1.29	0.188	17.0	4.17	6
C15015	443	1.61	0.237	21.1	5.29	6
C15019	561	2.02	0.300	26.6	6.74	6
C15024	712	2.54	0.386	33.5	8.79	5
C20015	555	3.53	0.396	34.7	7.7	7



Therefore, min. strength is 206MPa (local buckling)

Lysaght result is 16% higher (239MPa) vs CUFSM (206MPa) as we only restricted the lateral movement and not torsional rotation.

This affect can also be demonstrated using 100,000 Nmm/mm translational restraint instead of degree of freedom.

Roof Sheeting

Roof sheeting exists

Minor axis rotation restraint k_{ry} = 1.000E+5 Nmm/mm

Torsion restraint k_{rz} = 0.0 Nmm/mm

Roof Sheeting Restraints

The roof sheeting attached to the purlin is assumed to provide a continuous diaphragm shear restraint against minor axis rotation k_{ry} and a continuous torsion restraint k_{rz}. An appropriate value for k_{ry} is 100,000 Nmm/mm for screw-fastened sheeting. The magnitude of this restraint is appropriate but not excessive, and it enhances the load carrying capacities of purlins for which flexural-torsional buckling is the governing mode of failure. The value of k_{rz} can be determined by testing.

Purlins with clip-fastened sheeting can be designed by putting the values of k_{ry} and k_{rz} equal to zero. Zed sections with clip-fastened sheeting should have one or more rows of bridging which prevent lateral deflection and twisting of the cross-section.

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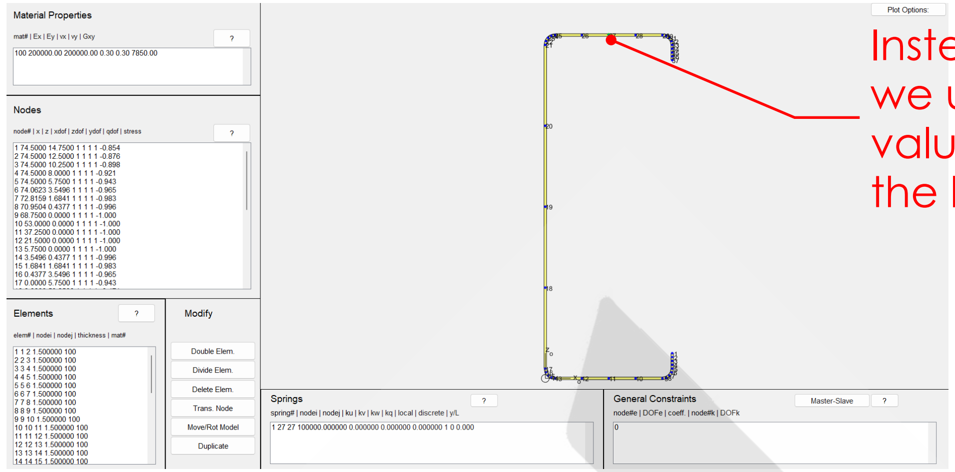
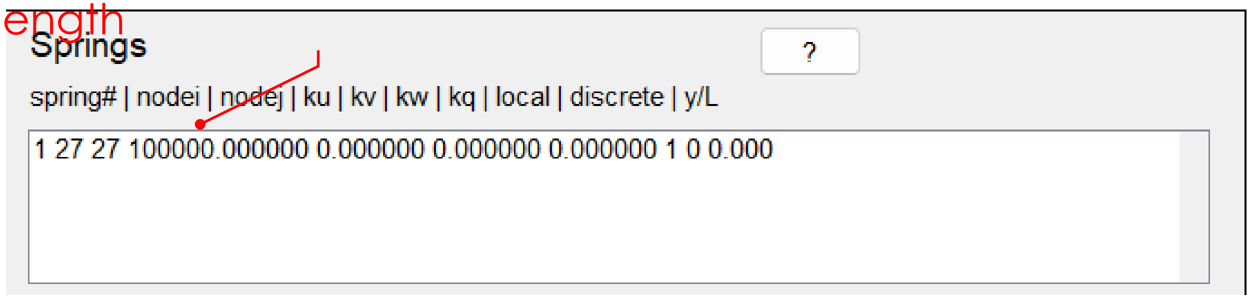
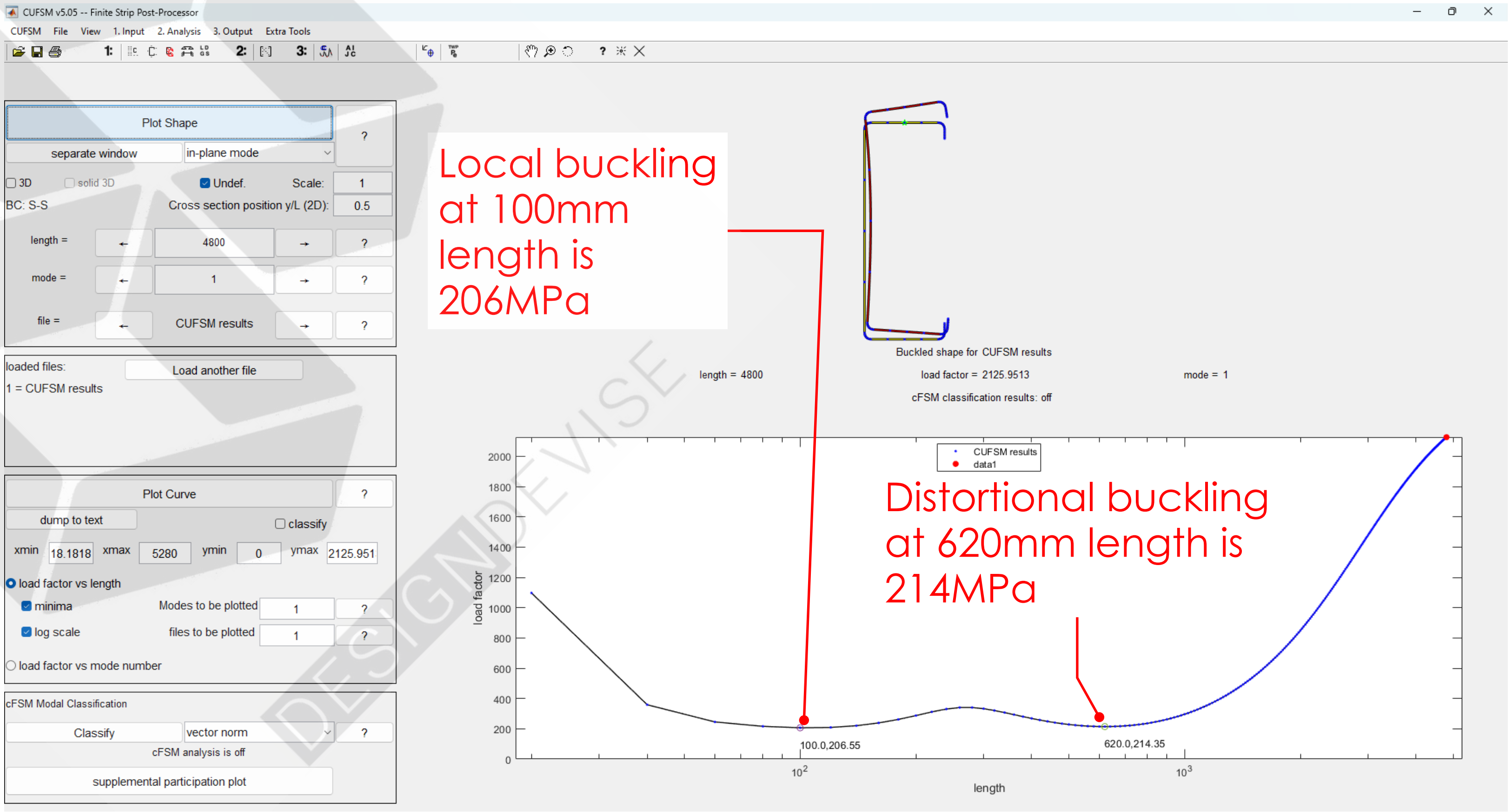


Instead of restraining lateral translation, we used x-direction point spring with a value of 100,000 Nmm/mm throughout the length



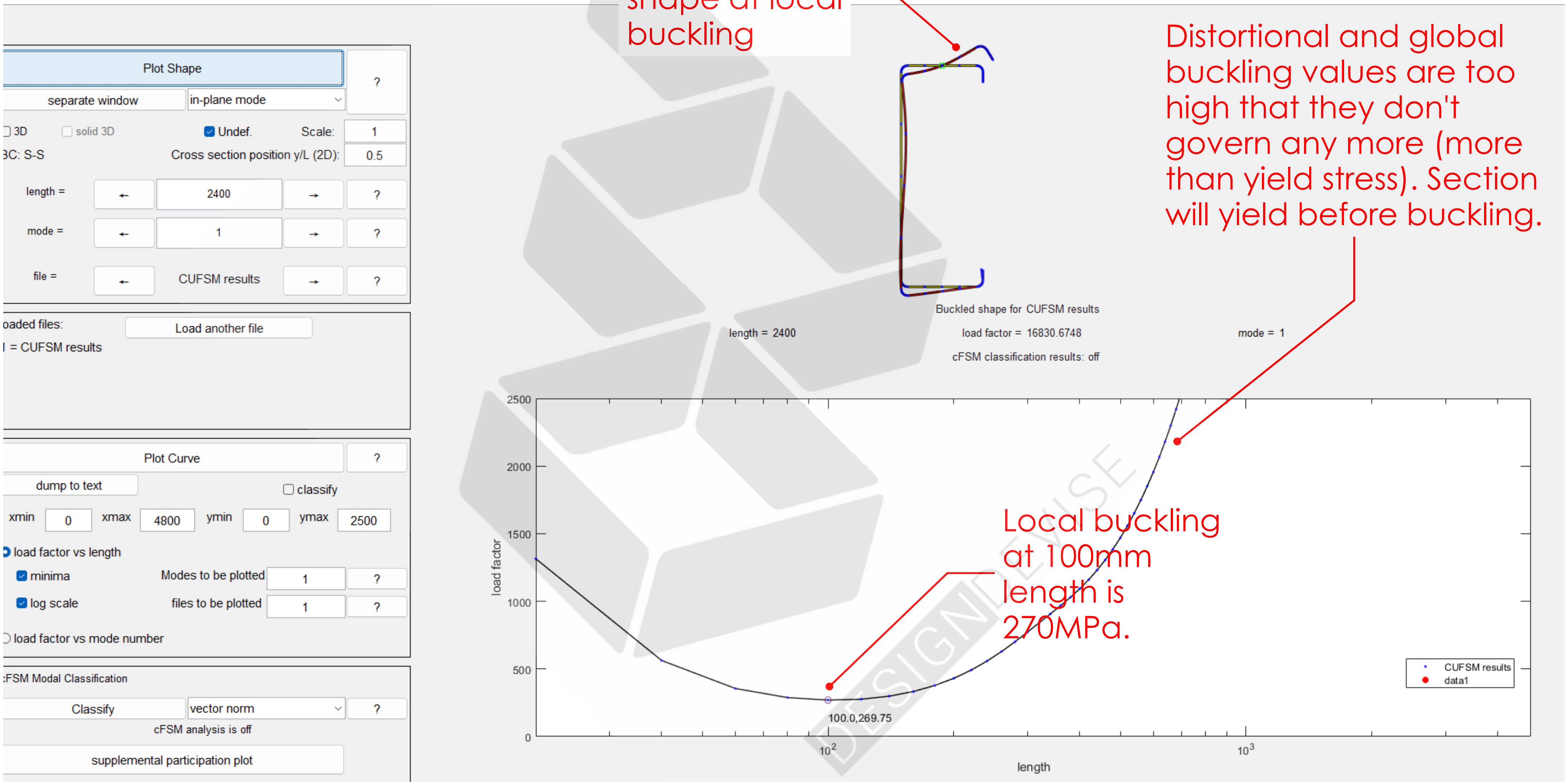
SAME RESULTS AS WITH DEGREE OF FREEDOM RESTRAINT



Local buckling at 100mm length is 206MPa

Distortional buckling at 620mm length is 214MPa

What happens if we also restraint the vertical movement in addition to horizontal at node 27 (middle of top flange) under downward loading?

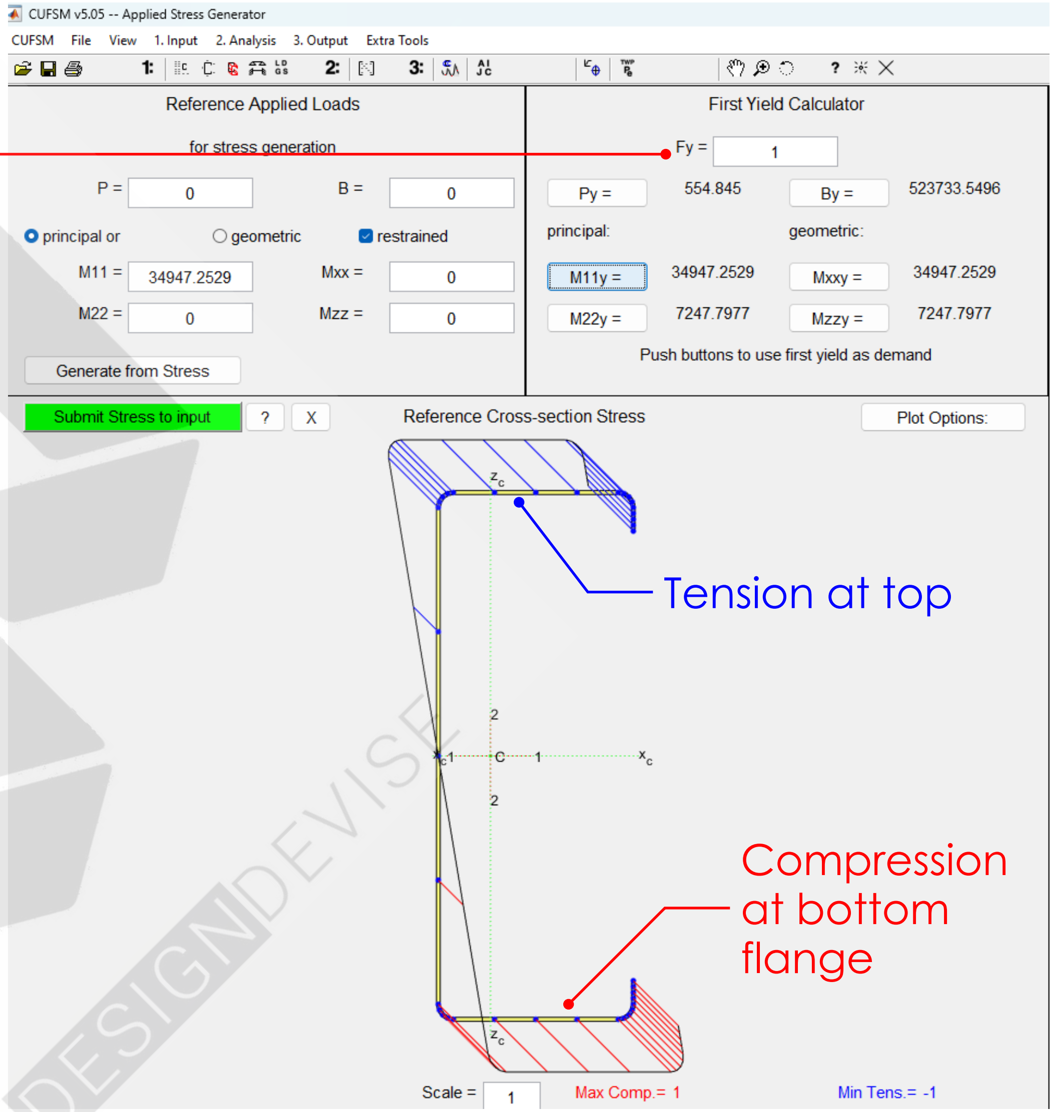


Interestingly, average of 206MPa (with lateral restraint only) and 270MPa (with torsional restraint only), is 238MPa, very close to 239MPa of Lysaght brochure capacity, for this purlin.

Values of rotational restraint commonly vary from around 200 N/rad to around 4000 N/rad. Within this range of values, both the channel and zed section purlins are sensitive to changes in rotational stiffness. Therefore, a standard value of rotational stiffness cannot be adopted and a procedure for determining the stiffness must be developed.

Now, let's go back to restraining the lateral freedom only at Node 27 but reverse the loading for uplift.

Instead of -1MPa we applied +1MPa for uplift loading.



Buckling diagram changed

Upward capacity with 0 bridging 1.51kN/m from the table.

This is equal to 4.35kN.m moment ($wl^2/8$).

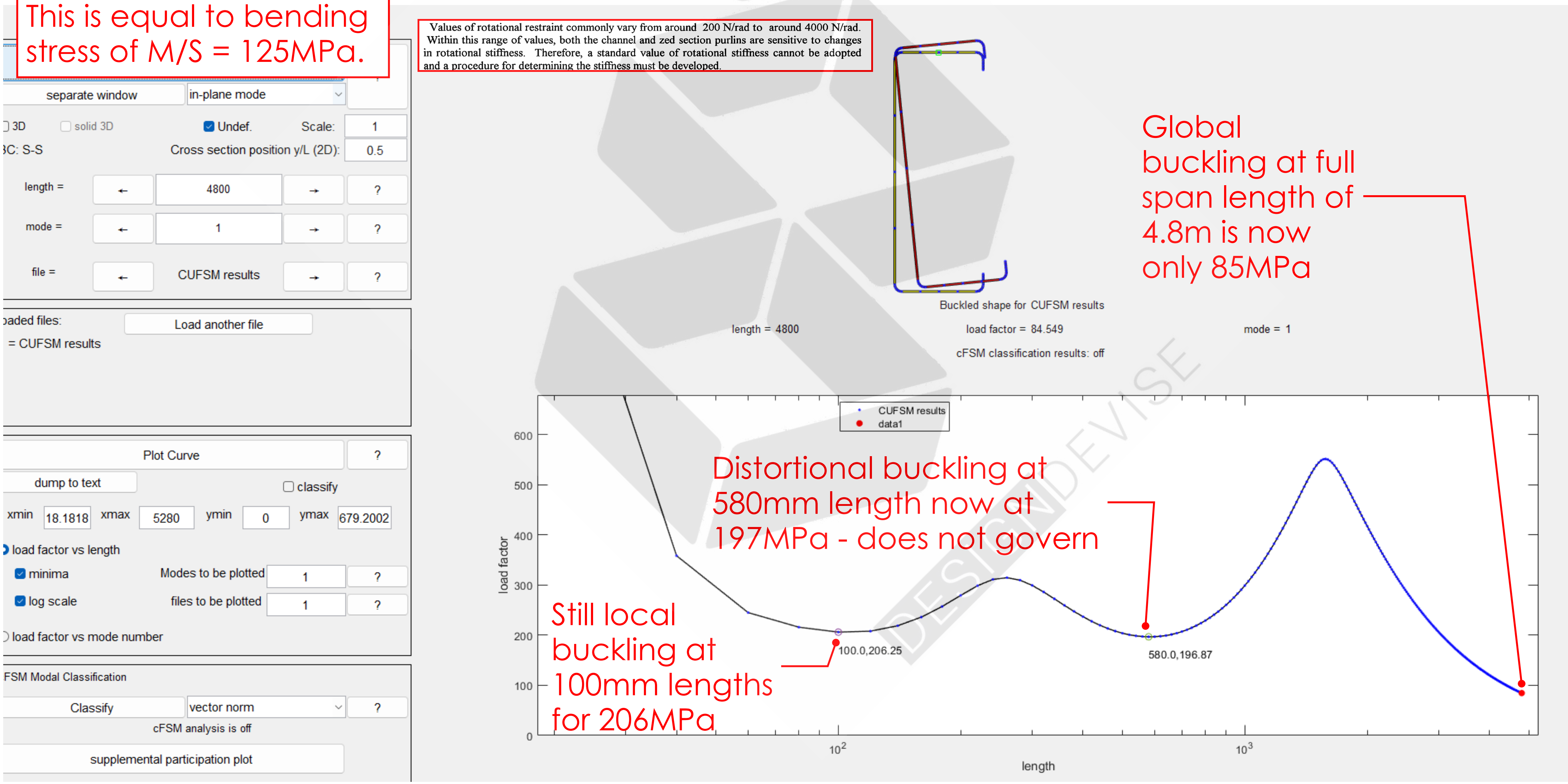
This is equal to bending stress of M/S = 125MPa.

Lysaght capacity 125MPa is about 47% higher than CUFSM (85MPa) because we only considered lateral restraint at top flange.

SINGLE SPANS

	Z/C 20015 (kN/m)					
	INWARD		OUTWARD			
Bridging >	0	1, 2, 3	0	1	2	3
Span mm						
3000	7.38	7.38	7.28	7.38	7.38	7.38
3300	6.10	6.10	5.47	6.10	6.10	6.10
3600	5.13	5.13	4.10	5.13	5.13	5.13
3900	4.33	4.37	3.13	4.37	4.37	4.37
4200	3.69	3.77	2.44	3.77	3.77	3.77
4500	3.17	3.28	1.86	3.28	3.28	3.28
4800	2.75	2.88	1.51	2.88	2.88	2.88

Values of rotational restraint commonly vary from around 200 N/rad to around 4000 N/rad. Within this range of values, both the channel and zed section purlins are sensitive to changes in rotational stiffness. Therefore, a standard value of rotational stiffness cannot be adopted and a procedure for determining the stiffness must be developed.



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Values of rotational restraint commonly vary from around 200 N/rad to around 4000 N/rad. Within this range of values, both the channel and zed section purlins are sensitive to changes in rotational stiffness. Therefore, a standard value of rotational stiffness cannot be adopted and a procedure for determining the stiffness must be developed.

Modeling of Cold-formed Purlins-sheeting Systems

S. Kitipornchai

R. M. Lucas

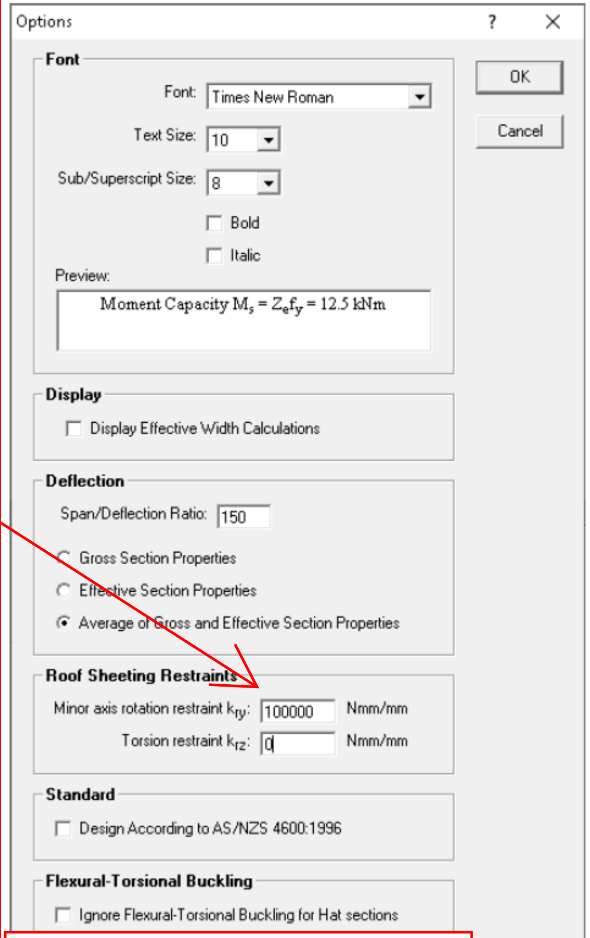
F. G. A. Al-Bermani

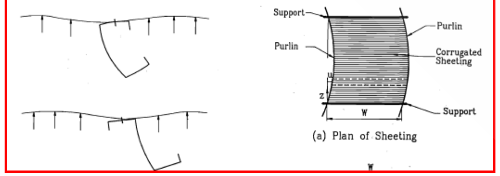
THE UNIVERSITY OF SYDNEY

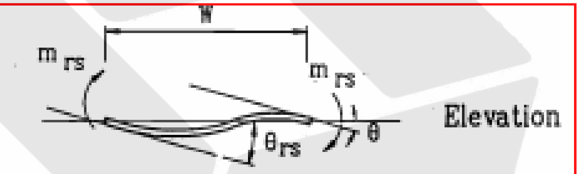
Centre for Advanced Structural Engineering

PURLIN

Analysis and Design of Cold-Formed Purlins According to AS/NZS 4600







$$k_{rs} = \frac{m_{rs}}{\theta_{rs}} = \frac{6EI}{bW}$$

(c) Sheeting Rotational Stiffness (k_{rs})

Fig. 2: Sheeting restraint

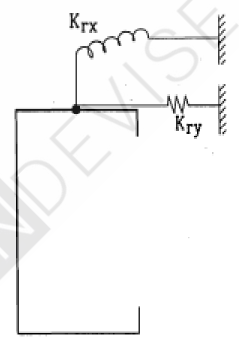
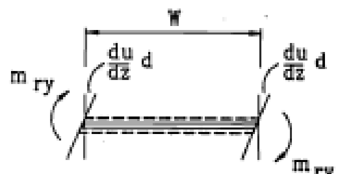


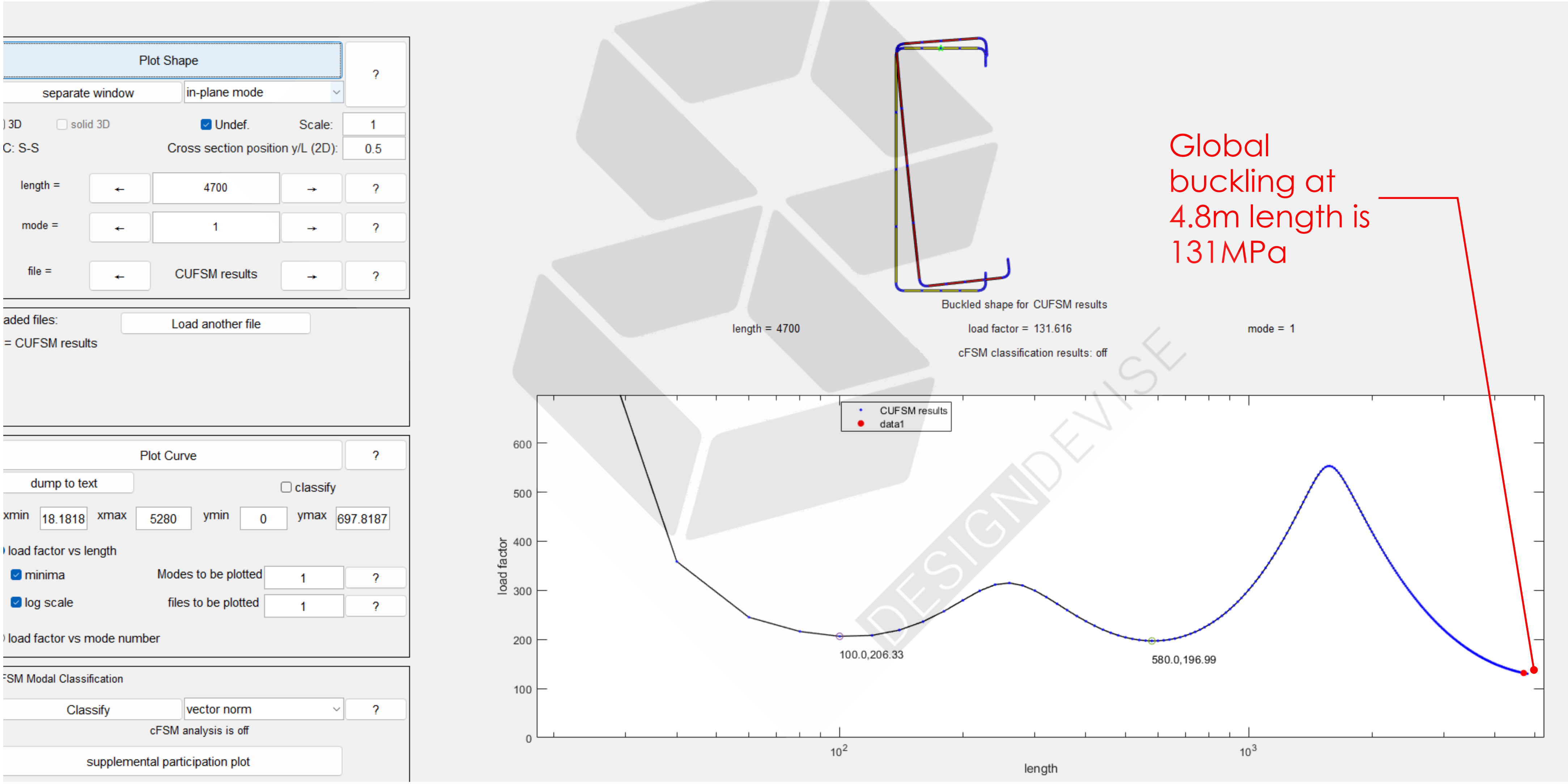
Fig. 3: Modeling of sheeting restraint



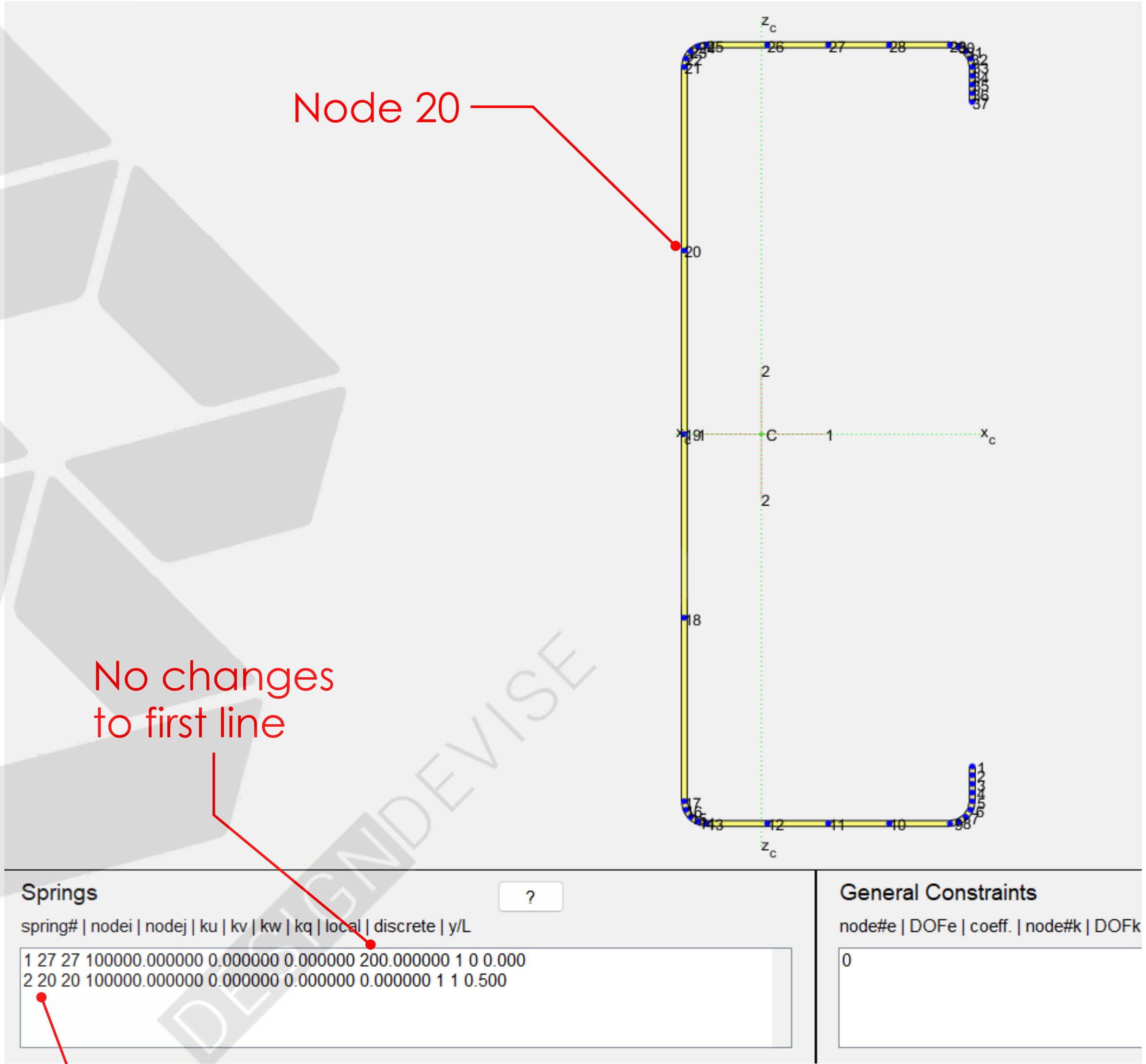
$$k_{ry} = m_{ry} / \frac{du}{dz}$$

(b) Sheeting Shear Stiffness (k_{ry})

Using a torsional restraint of 200N/rad in addition to 100,000 Nmm/mm translational restraint at top of middle flange (Node 27) provided similar values to Lysaght 131MPa for uplift global buckling.



Let's see if this combination gives close capacities for uplift with 1 bridging to that of Lysaght.

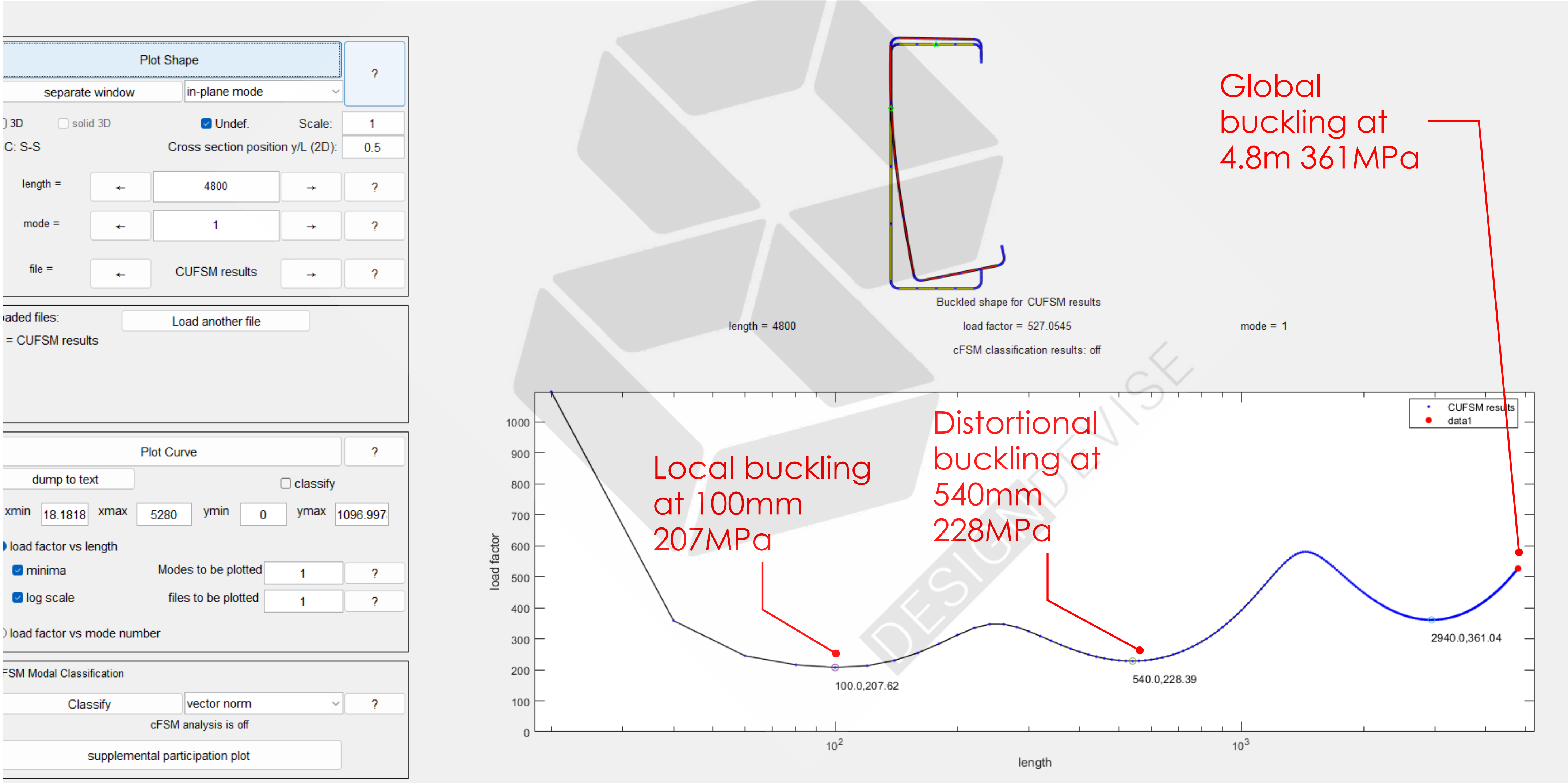


Added lateral restraint at half span to simulate 1 bridging

Min. is 207MPa local buckling (similar to downward loading of 206MPa). Lysaght is 239MPa.

SINGLE SPANS

	Z/C 20015 (kN/m)						
	INWARD		OUTWARD				L/150
Bridging >	0	1, 2, 3	0	1	2	3	
Span mm							
3000	7.38	7.38	7.28	7.38	7.38	7.38	10.60
3300	6.10	6.10	5.47	6.10	6.10	6.10	7.96
3600	5.13	5.13	4.10	5.13	5.13	5.13	6.28
3900	4.33	4.37	3.13	4.37	4.37	4.37	5.07
4200	3.69	3.77	2.44	3.77	3.77	3.77	4.15
4500	3.17	3.28	1.86	3.28	3.28	3.28	3.45
4800	2.75	2.88	1.51	2.88	2.88	2.88	2.88



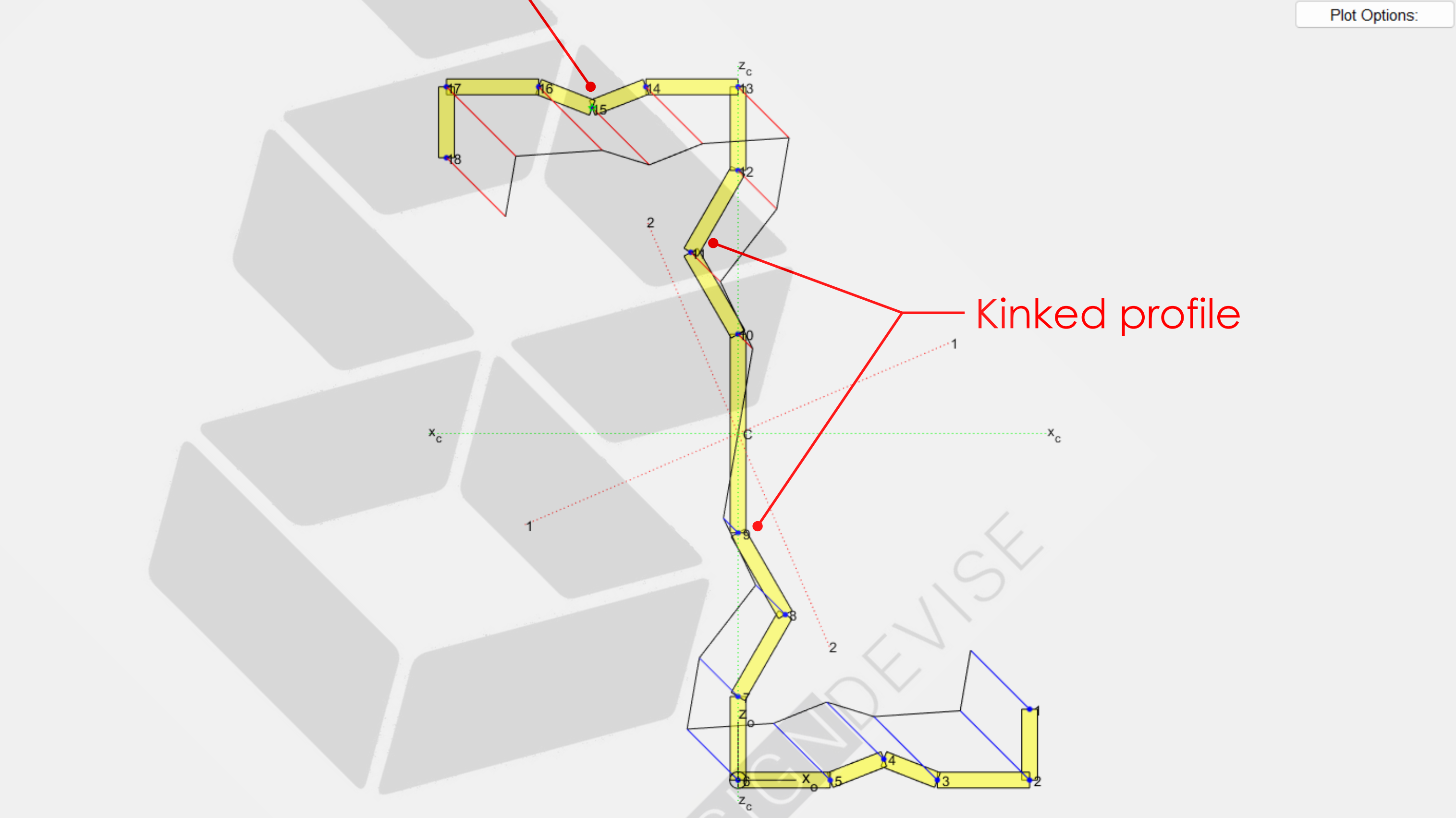
What does this very crude example tells?

1. if we model any shape in CUFSM using these concepts, the software capacities will be a close match to the real capacities.
2. Torsional restraint should be chosen with caution. Can solar panels provide torsional restraint to rails/purlins?
3. Buckling reduces capacity. Sections buckle well before yielding if restraints are not available.
4. A translational restraint of 100,000 Nmm/mm was equivalent to 0 degree of freedom in the the lateral X direction.
5. For C20015 purlin:
Global buckling for uplift loading with 1 row of bridging was equal to local buckling under downward loading without bridging (also confirmed from Lysaght brochure)

Let's now model LC90 profile with same concept with no bridging. Simply supported 3m span and sharp corners.

Translational restraint applied to Node 15

Kinked profile



Material Properties

mat# | Ex | Ey | vx | vy | Gxy

100 200000.00 200000.00 0.30 0.30 80000.00

Nodes

node# | x | z | xdof | zdof | ydof | qdof | stress

1 37.0000 9.0000 1 1 1 1 -0.850
2 37.0000 0.0000 1 1 1 1 -1.000
3 25.3023 0.0000 1 1 1 1 -0.916
4 18.5000 2.6700 1 1 1 1 -0.823
5 11.6977 0.0000 1 1 1 1 -0.819
6 0.0000 0.0000 1 1 1 1 -0.735
7 0.0000 10.6077 1 1 1 1 -0.558
8 6.0000 21.0000 1 1 1 1 -0.427
9 0.0000 31.3923 1 1 1 1 -0.211
10 0.0000 56.6077 1 1 1 1 0.211
11 -6.0000 67.0000 1 1 1 1 0.427
12 0.0000 77.3923 1 1 1 1 0.558
13 0.0000 88.0000 1 1 1 1 0.735
14 -11.6977 88.0000 1 1 1 1 0.819
15 -18.5000 85.3300 1 1 1 1 0.823
16 -25.3023 88.0000 1 1 1 1 0.916
17 -37.0000 88.0000 1 1 1 1 1.000

Elements

elem# | nodei | nodej | thickness | mat#

1 1 2 2.000000 100
2 2 3 2.000000 100
3 3 4 2.000000 100
4 4 5 2.000000 100
5 5 6 2.000000 100
6 6 7 2.000000 100
7 7 8 2.000000 100
8 8 9 2.000000 100
9 9 10 2.000000 100
10 10 11 2.000000 100
11 11 12 2.000000 100
12 12 13 2.000000 100
13 13 14 2.000000 100
14 14 15 2.000000 100

Modify

Double Elem.
Divide Elem.
Delete Elem.
Trans. Node
Move/Rot Model
Duplicate

Springs

spring# | nodei | nodej | ku | kv | kw | kq | local | discrete | y/L

1 15 15 100000.000000 0.000000 0.000000 0.000000 1 0 0.000

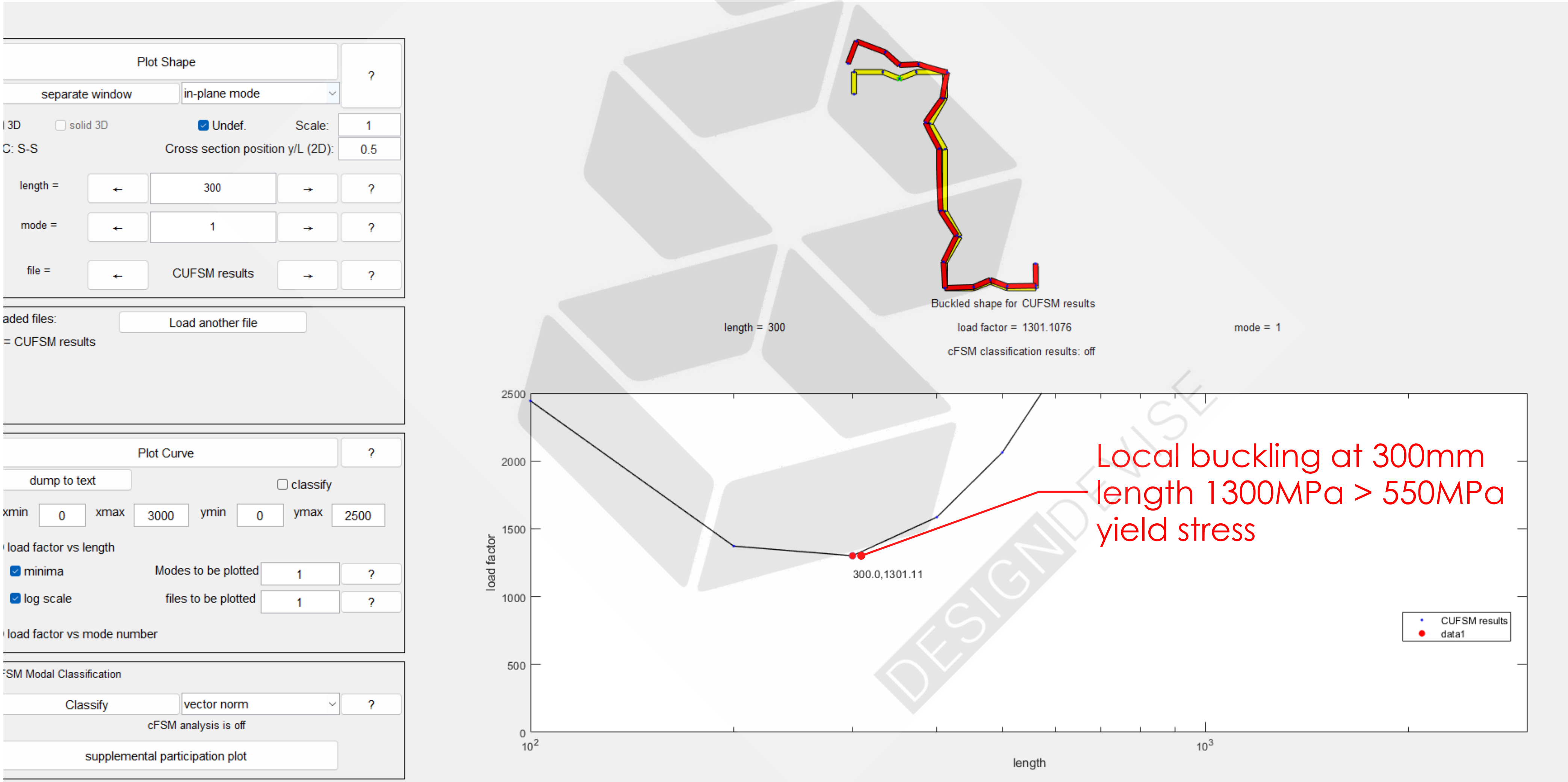
General Constraints

Master-Slave

node#e | DOFe | coeff. | node#k | DOFk

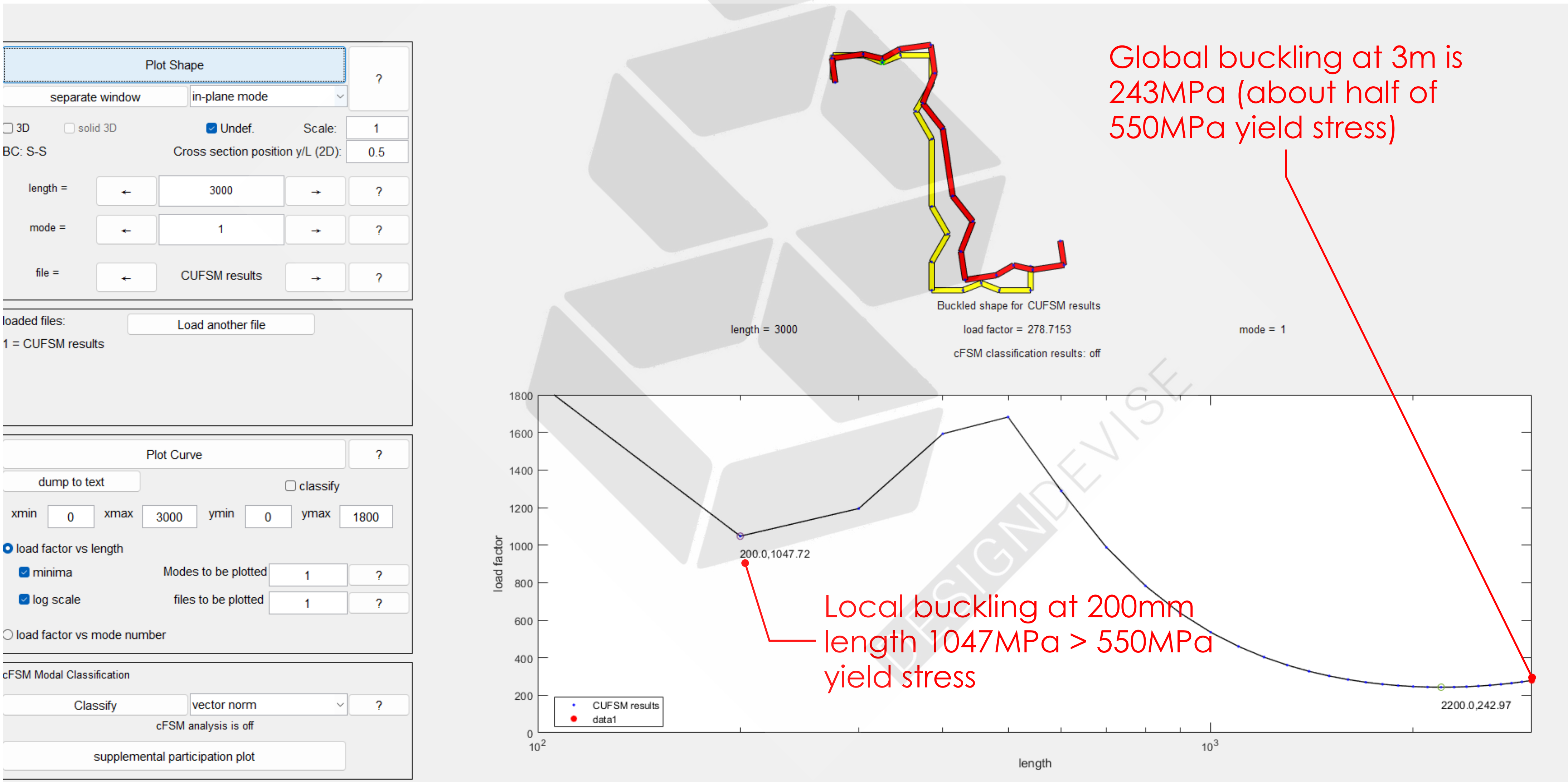
0

Buckling does not govern under downward loading.



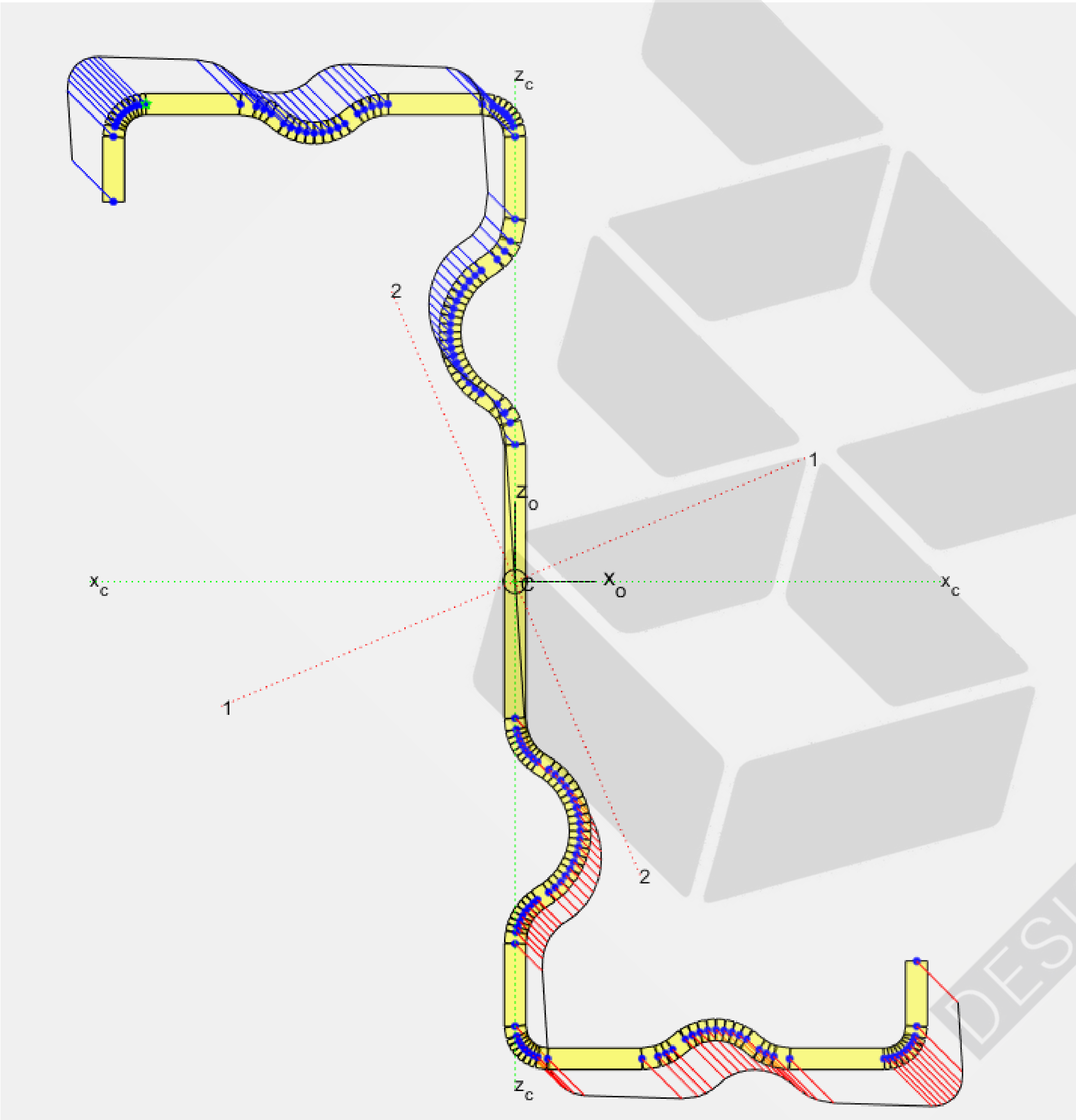
Global buckling is still less than Yield stress

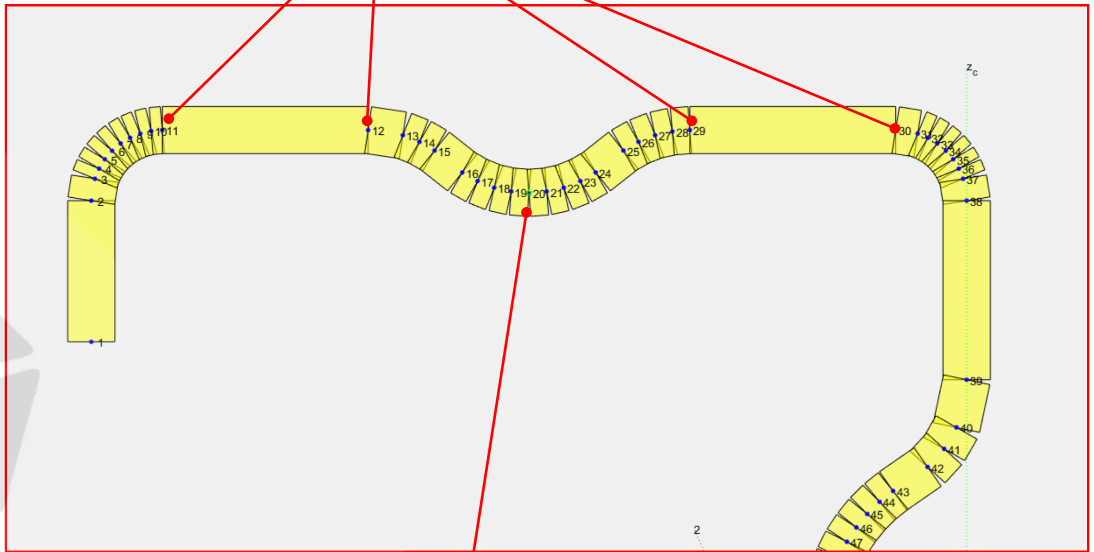
TOP LATERAL + TORSIONAL RESTRAINT



Let's refine the profile to avoid sharp corners, for that we subdivided the shape into 153 elements capturing x and y coordinate for each point in CAD through a custom in house LISP

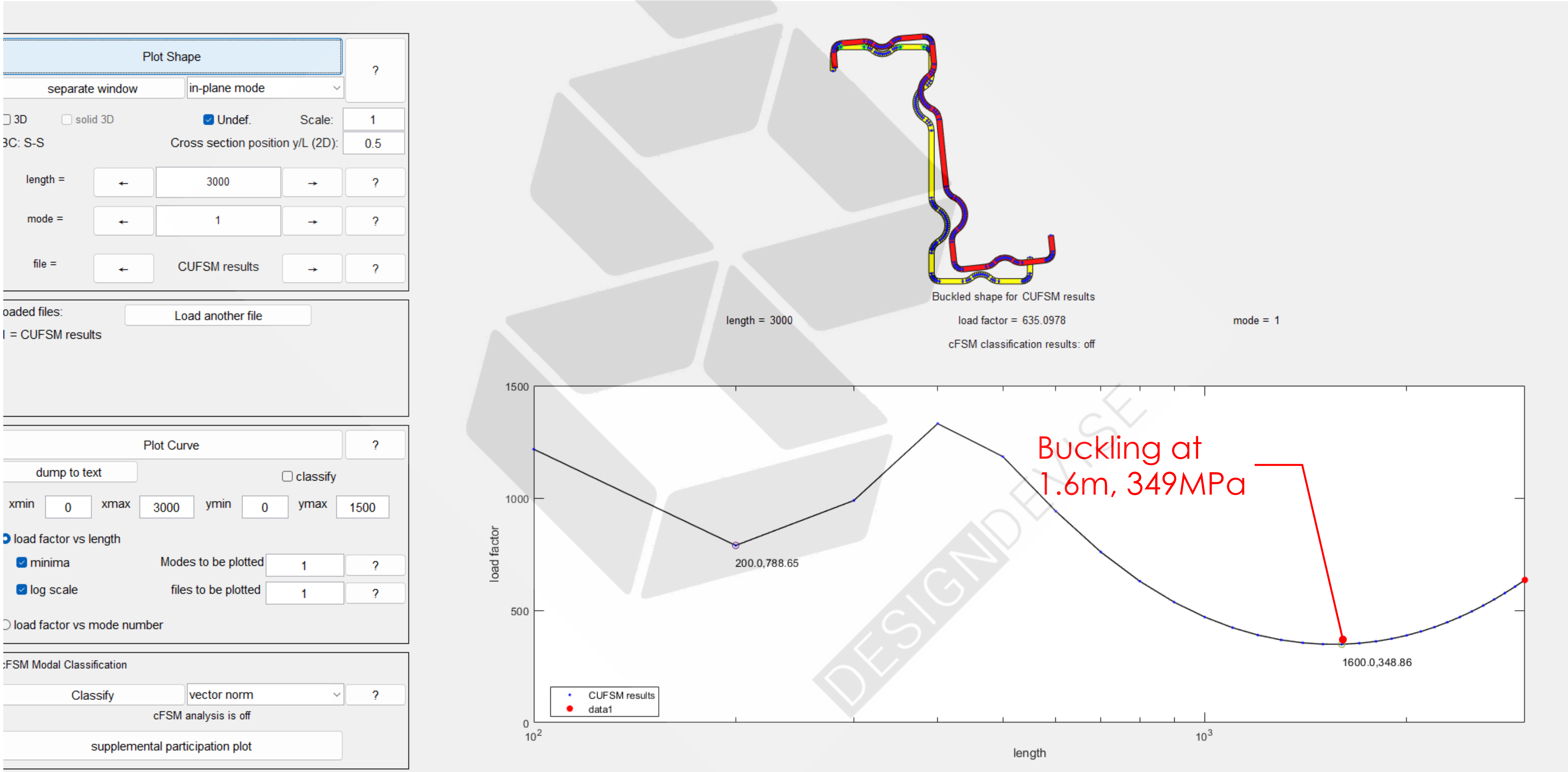
Let's apply restraints to four points: Node 11, 12, 29 & 30





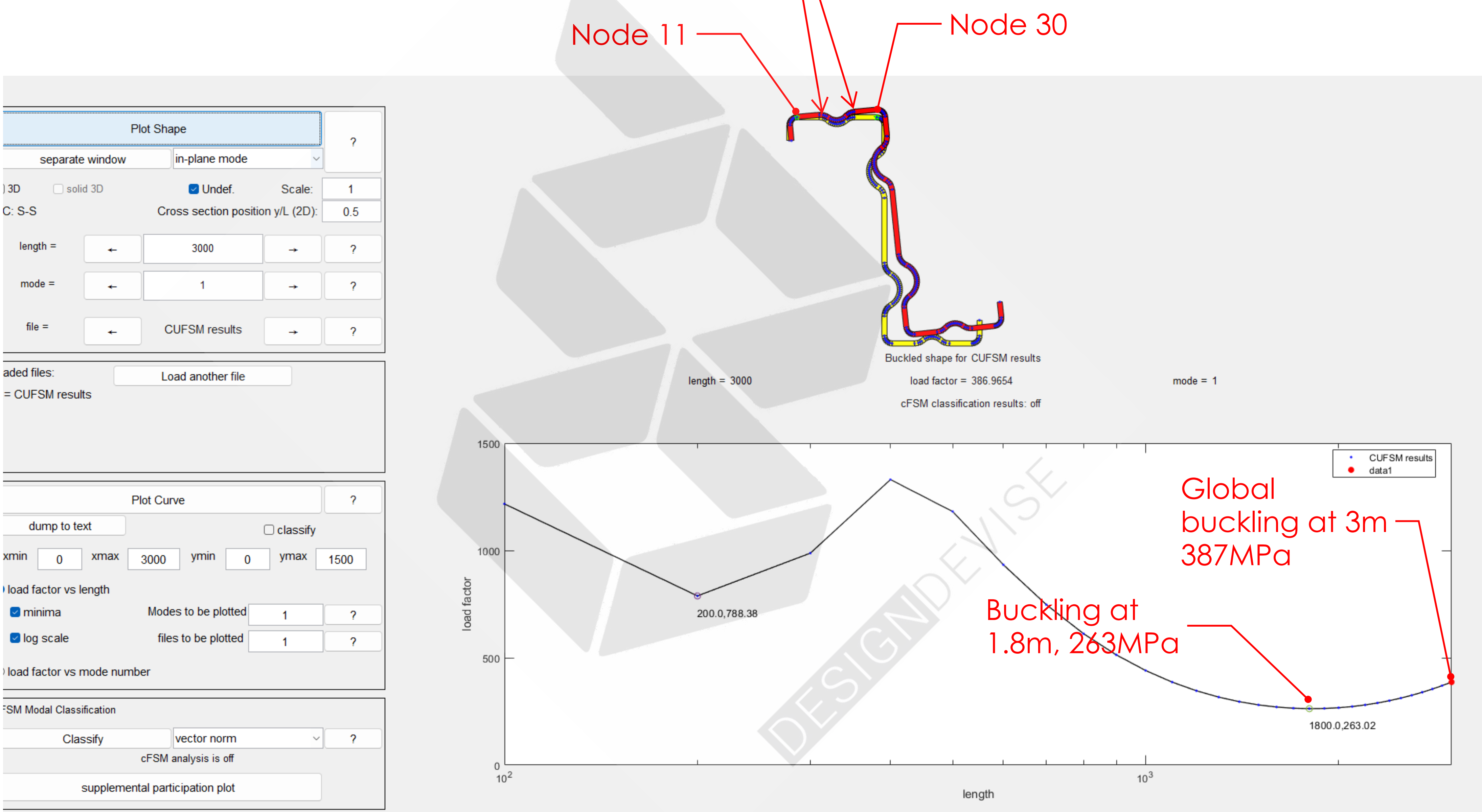
Restraint applied at mid-flange width did not improve results

Apply excessive restraint at four top points immensely helped. Local and Global buckling is not governing, however now, distortional buckling governs with a wavelength of 1600mm with a value of 349MPa.

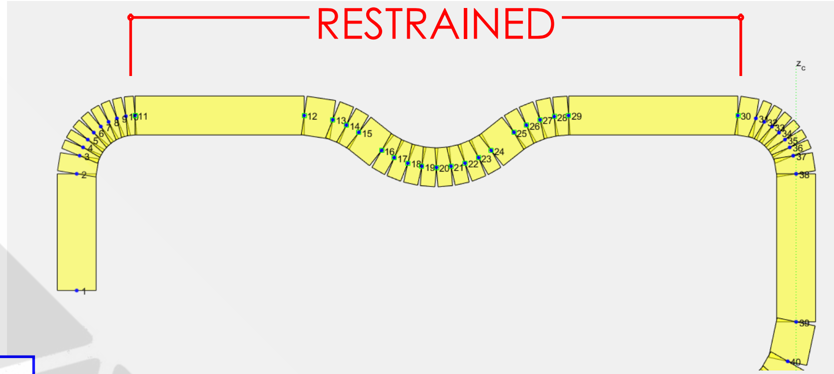


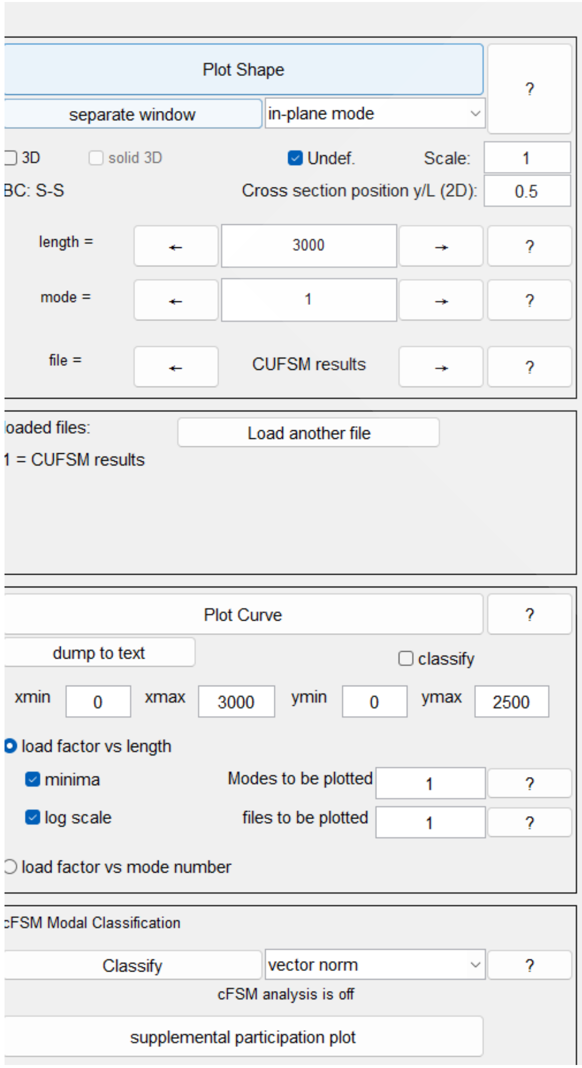
In this example, instead of four, only two points were restrained (Node 11 & 30)

Similar results if restraints are applied to Node 12 & 29

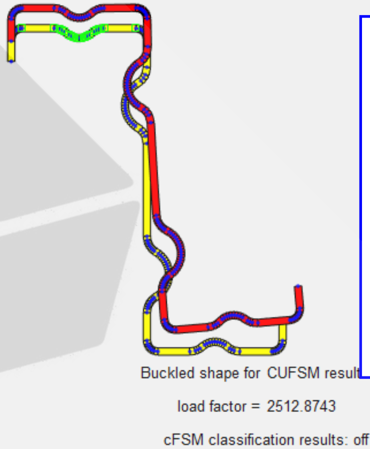


In this last example, we applied 0 degree of X-direction freedom (full lateral restraint) on the top flange from Node 10 to 30, but no torsional restraint, no buckling mode governs.

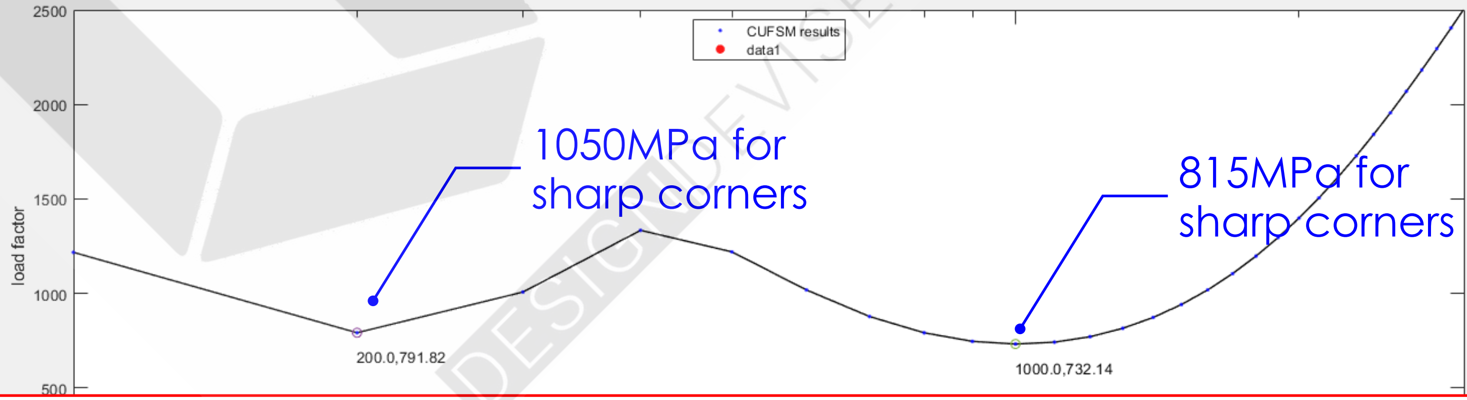




However, major difference in restraining the top flange of this section vs Lysaght C20015 which offered no improvement.



We compared this concept with the sharp corner profile example and found that sharp corners yielded better results. In summary there was no need for the rounded corners refinement in this software.



So the Final Question: Is this assumption correct that solar panels can restrain the full top flange? As under partial restraint flange, buckling still governs. And if the answer is YES, then can solar panels handle that much compression? (X-drection restraining forces from two purlins)???