Stiffened Cross-section

Scia Engineer Version 10.0.86

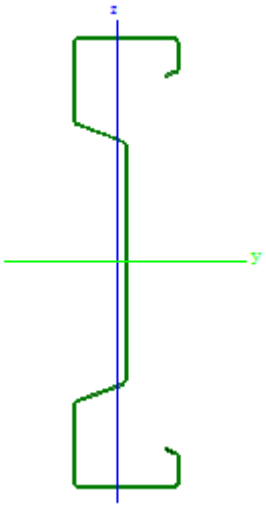
Introduction

In this benchmark the effective section calculation for a stiffened cross-section is evaluated.

More specifically the effective area in compression for a Sadef Sigma Plus section of type SADEFSP 420x2.00 is determined. This section contains both internal stiffeners in the web and double edge folds at the flange tips.

The cross-section is made of S390GD+Z and has a metallic coating of 0,5 mm.

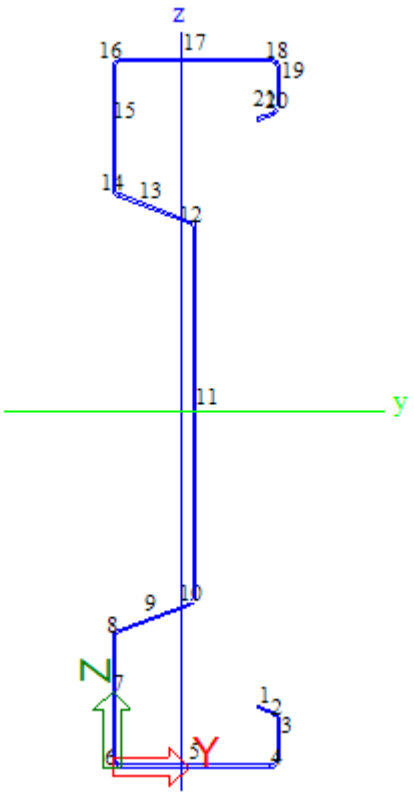
The results are verified by a manual calculation; therefore the optional stiffener iterations are not applied.



Reference Results

The results are checked by a manual calculation.

The following picture shows the part numbers for the different elements of the cross-section:



Since the section is symmetric, the reductions are calculated for one half of the section.

Geometry	
Formcode	123 - Cold formed Sig...
s [mm]	1,500
r [mm]	4,000
B [mm]	100,000
H [mm]	420,000
H1 [mm]	80,000
H2 [mm]	97,300
c [mm]	30,000
c2 [mm]	14,000
b2 [mm]	48,000
alpha2 [deg]	20,05

From the Initial Shape

1: DEF	w = 9,60 mm
3: I	w= 22,25 mm
5: I	w= 89 mm
7: I	w= 70,69 mm
9: RI	w= 44,70 mm
11: I	w= 218,36 mm

r_m = 4 + 1,50 / 2 = 4,75 mm

From Profile library shape the depression angle is determined as 21,252 degrees.

Notional widths

1: DEF	b_p = 9,60 + 4,75 * sin ((90 - 20,05) / 2) = 12,323 mm
3: I	b_p = 22,25 + 4,75 * sin ((90 - 20,05) / 2) + 4,75 * sin (90 / 2) = 28,33 mm
5: I	b_p = 89 + 4,75 * sin (90 / 2) + 4,75 * sin (90 / 2) = 95,718 mm
7: I	b_p = 70,69 + 4,75 * sin (90 / 2) + 4,75 * sin ((90 - 21,252) / 2) = 76,75 mm
9: RI	b_p = 44,70 + 4,75 * sin ((90 - 21,252) / 2) + 4,75 * sin ((90 - 21,252) / 2) = 50,06 mm
11: I	b_p = 218,36 + 4,75 * sin ((90 - 21,252) / 2) + 4,75 * sin ((90 - 21,252) / 2) = 223,724 mm

Epsilon = sqrt (235 / 390) = 0,77625

Slenderness Limit for internal compression elements in case psi = 1,00: 0,5 + sqrt (0,085 - 0,055 * 1,00) = 0,673205

Slenderness Limit for outstand compression elements: 0,748

Centerline Lengths of web elements

7: I	lc = 76,75 + 4,75 * [tan (90 / 2) - sin (90 / 2)] + 4,75 * [tan ((90 - 21,252) / 2) - sin ((90 - 21,252) / 2)] = 78,708656 mm
9: RI	lc = 50,06 + 4,75 * [tan ((90 - 21,252) / 2) - sin ((90 - 21,252) / 2)] + 4,75 * [tan ((90 - 21,252) / 2) - sin ((90 - 21,252) / 2)] = 51,1948267 mm
11: I	lc = 223,724 + 4,75 * [tan ((90 - 21,252) / 2) - sin ((90 - 21,252) / 2)] + 4,75 * [tan ((90 - 21,252) / 2) - sin ((90 - 21,252) / 2)] = 224,8588267 mm
13: RI	lc = 50,06 + 4,75 * [tan ((90 - 21,252) / 2) - sin ((90 - 21,252) / 2)] + 4,75 * [tan ((90 - 21,252) / 2) - sin ((90 - 21,252) / 2)] = 51,1948267 mm
15: I	lc = 76,75 + 4,75 * [tan (90 / 2) - sin (90 / 2)] + 4,75 * [tan ((90 - 21,252) / 2) - sin ((90 - 21,252) / 2)] = 78,708656 mm

Local buckling

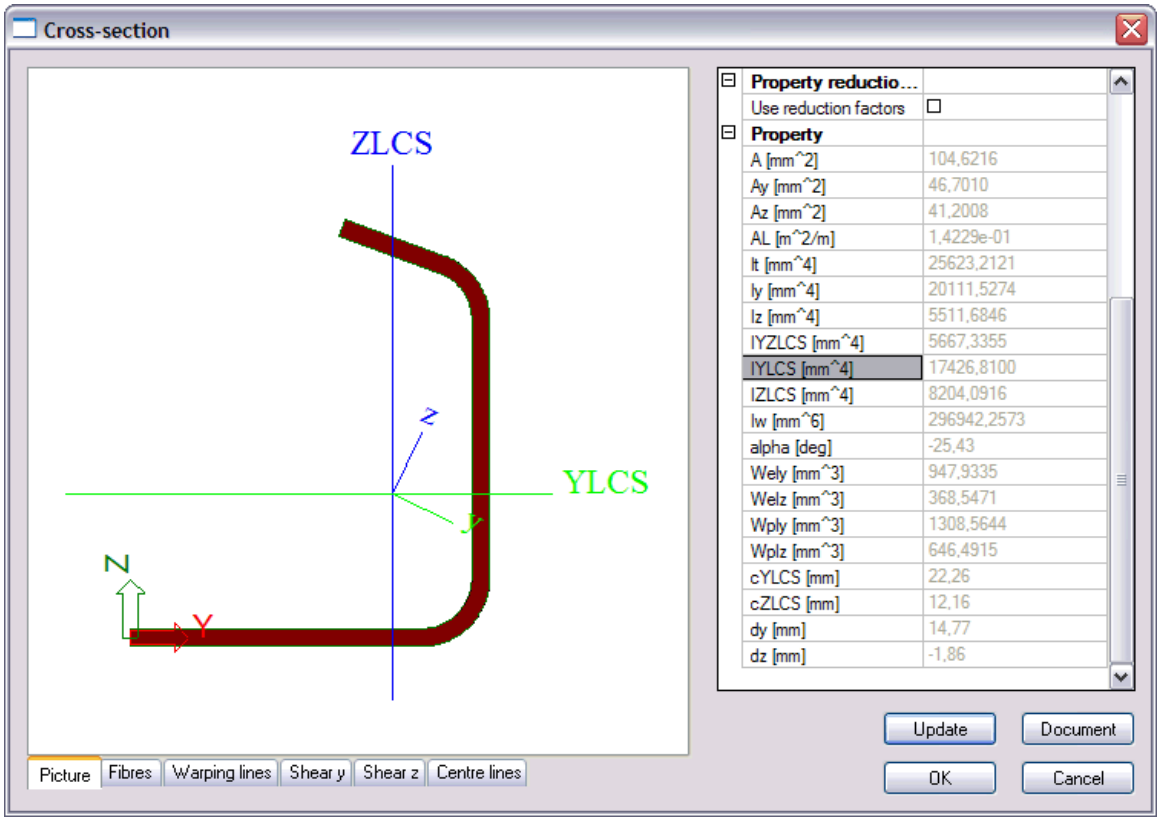
1: DEF	k = 0,43 Lambda,p = (12,323 / 1,50) / (28,4 * 0,77625 * sqrt(0,43)) = 0,568 => Rho = 1,00 => b_{eff} = 1,00 * 12,323 = 12,323 mm
3: I	k = 4 Lambda,p = (28,33 / 1,50) / (28,4 * 0,77625 * sqrt(4)) = 0,4284 => Rho = 1,00 => b_{eff} = 1,00 * 28,33 = 28,33 mm => be1 = be2 = 0,5 * 28,33 = 14,165 mm
5: I	k = 4 Lambda,p = (95,718 / 1,50) / (28,4 * 0,77625 * sqrt(4)) = 1,4473 => Rho = 0,5859 => b_{eff} = 0,5859 * 95,718 = 56,081 mm => be1 = be2 = 0,5 * 56,081 = 28,04 mm
7: I	k = 4 Lambda,p = (76,75 / 1,50) / (28,4 * 0,77625 * sqrt(4)) = 1,160 => Rho = 0,69857 => b_{eff} = 0,69857 * 76,75 = 53,615 mm => be1 = be2 = 0,5 * 53,615 = 26,8076 mm
9: RI	No reduction for local buckling
11: I	k = 4 Lambda,p = (223,724 / 1,50) / (28,4 * 0,77625 * sqrt(4)) = 3,383 => Rho = 0,27637 => b_{eff} = 0,27637 * 223,724 = 61,83 mm => be1 = be2 = 0,5 * 61,83 = 30,915 mm

Distortional buckling Double Edge Fold 1-2-3-4-5

1:	Fully effective => w = 9,60 mm
2:	Rounding with angle (90 - 20,05)° => w = 2 * pi * 4,75 * ((90 - 20,05)/360) = 5,80 mm
3:	Fully effective => w = 22,25 mm
4:	Rounding with angle 90° => w = 2 * pi * 4,75 * (90/360) = 7,4613 mm
5:	be2 = 28,04 mm => be2,w = 28,04 - 4,75 * sin (90 / 2) = 24,681 mm

=> As = [9,60 + 5,80 + 22,25 + 7,4613 + 24,681] * 1,50 = 104,69 mm^2

This section is inputted as a general cross-section to calculate the section properties:



Is = IYLCS = 17426,81 mm^4

b1 = 100 - (1,5 / 2) - 1,5 - 4 - 24,681 + cYLCS = 91,33 mm
b2 = 91,33 mm (symmetrical section)
kf = 1,00 (symmetrical section in compression)

hw = sum of the centerline lengths of all elements in the web (7, 9, 11, 13, 15) = 78,708656 + 51,1948267 + 224,8588267 + 51,1948267 + 78,708656 = 484,67 mm

E = 210000 N/mm^2
mu = 0,3

=> K = [210000 * (1,5)^3] / [4 * (1 - (0,3)^2)] * [1 / [91,33^2 * 484,67 + 91,33^3 + 0,5 * 91,33 * 91,33 * 484,67 * 1,00]] = 0,02852567 N/mm^2

=> Sigma,cr,s = [2 * sqrt (0,02852567 * 210000 * 17426,81)] / 104,69 = 195,192 N/mm^2

=> Lambda,d = sqrt (390 / 195,192) = 1,4135 >= 1,38

=> Chi,d = 0,66 / 1,4135 = 0,4669198

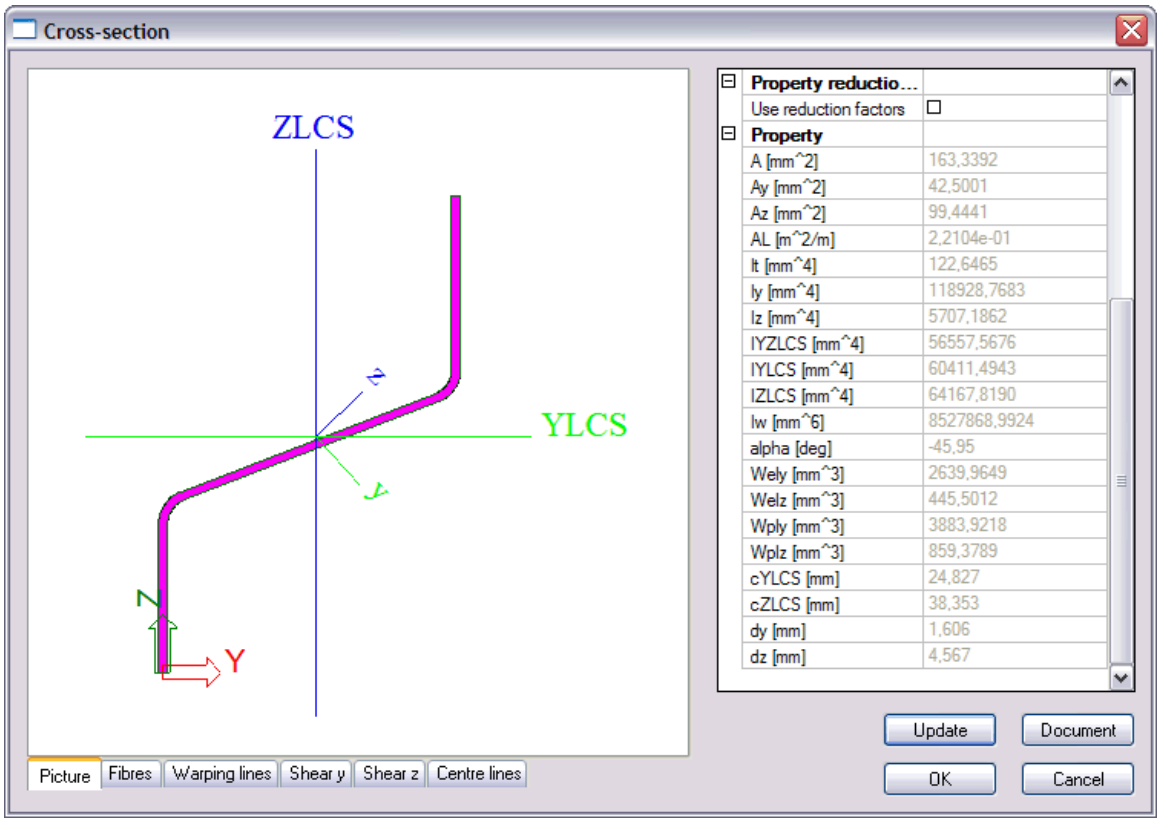
=> As,red = 0,4669198 * 104,69 = 48,8818 mm^2

Distortional buckling Intermediate stiffener 7-8-9-10-11

7:	be2 = 26,8076 mm => be2,w = 26,8076 - 4,75 * sin ((90 - 21,252) / 2) = 24,1258 mm
8:	Rounding with angle (90 - 21,252)° => w = 2 * pi * 4,75 * ((90 - 21,252)/360) = 5,70 mm
9:	Fully effective => w = 44,70 mm
10:	Rounding with angle (90 - 21,252)° => w = 2 * pi * 4,75 * ((90 - 21,252)/360) = 5,70 mm
11:	be2 = 30,915 mm => be2,w = 30,915 - 4,75 * sin ((90 - 21,252) / 2) = 28,2332 mm

=> As = [24,1258 + 5,70 + 44,70 + 5,70 + 28,2332] * 1,50 = 162,6885 mm^2

This section is inputted as a general cross-section to calculate the section properties:



Property reductio...	
Use reduction factors	☐
Property	
A [mm^2]	163,3392
Ay [mm^2]	42,5001
Az [mm^2]	99,4441
AL [m^2/m]	2,2104e-01
It [mm^4]	122,6465
Iy [mm^4]	118928,7683
Iz [mm^4]	5707,1862
IYZLCS [mm^4]	56557,5676
IYLCS [mm^4]	60411,4943
IZLCS [mm^4]	64167,8190
Iw [mm^6]	8527868,9924
alpha [deg]	-45,95
Wely [mm^3]	2639,9649
Welz [mm^3]	445,5012
Wply [mm^3]	3883,9218
Wplz [mm^3]	859,3789
cYLCS [mm]	24,827
cZLCS [mm]	38,353
dy [mm]	1,606
dz [mm]	4,567

Is = IZLCS = 64167,8190 mm^4

b1 = (1,5 / 2) + 4 + 70,69 - 24,1258 + cZLCS = 89,6672 mm

centerline length element 11: 218,36 + 4,75 * tan ((90 - 21,252) / 2) + 4,75 * tan ((90 - 21,252) / 2) = 224,8585 mm

b2 = 224,8585 - 4,75 * tan ((90 - 21,252) / 2) - 28,2332 + (77,868 - CZLCS) = 232,891 mm

E = 210000 N/mm^2
mu = 0,3

=> K = [0,25 * (89,6672 + 232,891) * 210000 * 1,5^3] / [(1 - 0,3^2) * 89,6672 * 89,6672 * 232,891 * 232,891] = 0,14402 N/mm^2

=> Sigma,cr,s = [2 * sqrt (0,14402 * 210000 * 64167,8190)] / 162,6885 = 541,571 N/mm^2

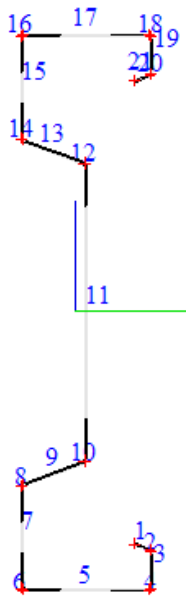
=> Lambda,d = sqrt (390 / 541,571) = 0,8486 => between 0,65 and 1,38

=> Chi,d = 1,47 - 0,723 * 0,8486 = 0,8565

=> As,red = 0,8565 * 162,6885 = 139,34 mm^2

Effective Area
A_{eff} = 1132,8549 - 2 * (1 - 0,5859) * 95,718 * 1,5 - 2 * (1 - 0,69857) * 76,75 * 1,5 - (1 - 0,27637) * 223,724 * 1,5 - 2 * (104,69 - 48,8818) - 2 * (162,6885 - 139,34) = 543,387 mm^2

Scia Engineer Results



Id	bp [mm]	f1 [N/mm²]	f2 [N/mm²]	psi [-]	k [-]	lambda,p [-]	lambda,p,red [-]	rho [-]	be [mm]	be1 [mm]	be2 [mm]	Effective shape
1	12,328	390,000	390,000	1,000	0,430	0,569		1,000	12,328			
3	28,331	390,000	390,000	1,000	4,000	0,428		1,000	28,331	14,165	14,165	
5	95,718	390,000	390,000	1,000	4,000	1,447		0,586	56,083	28,042	28,042	
7	76,755	390,000	390,000	1,000	4,000	1,161		0,698	53,599	26,800	26,800	
9	50,112	390,000	390,000	1,000				1,000	50,112			
11	223,769	390,000	390,000	1,000	4,000	3,383		0,276	61,836	30,918	30,918	
13	50,112	390,000	390,000	1,000				1,000	50,112			
15	76,755	390,000	390,000	1,000	4,000	1,161		0,698	53,599	26,800	26,800	
17	95,718	390,000	390,000	1,000	4,000	1,447		0,586	56,083	28,042	28,042	
19	28,331	390,000	390,000	1,000	4,000	0,428		1,000	28,331	14,165	14,165	
21	12,328	390,000	390,000	1,000	0,430	0,569		1,000	12,328			

Id	As [mm²]	Is [mm⁴]	b1 [mm]	b2 [mm]	hw [mm]	kf [-]	K [N/mm²]	sigma,cr [N/mm²]	lambda,d [-]	Chi,d [-]	As,red [mm²]
1	104,6710	17554,6006	91,133	91,133	484,963	1,000	0,029	196,335	1,409	0,468	49,0158
9	162,7588	63956,7668	89,216	232,503	0,000	0,000	0,146	543,377	0,847	0,857	139,5625
13	162,7588	63956,6243	232,503	89,216	0,000	0,000	0,146	543,377	0,847	0,857	139,5624
21	104,6710	17554,5925	91,133	91,133	484,963	1,000	0,029	196,335	1,409	0,468	49,0158

A [mm²]	Ay [mm²]	Az [mm²]	It [mm⁴]	Iy [mm⁴]	Iz [mm⁴]	Iw [mm⁶]	Wely [mm³]	Welz [mm³]
543,8831	367,6911	235,2546	298,4925	14764292,3497	586680,2284	16410887,9779	70306,1465	8673,1779

Comments

- The results correspond to the benchmark results.
- A slight difference is due to rounding errors.