GRISPE

Guidelines and **R**ecommendations for **I**ntegrating **S**pecific **P**rofiled steel sheets in the **E**urocodes (**GRISPE**)

WP4 Doc 5 Version 01

Background guidance for EN 1993–1–3

Working Package 4

Deliverable D 4.5

Guidelines and Recommendations for Integrating Specific Profiled Steels sheets in the Eurocodes (GRISPE)

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Summary

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Introduction

Plank profiles, mainly for aesthetics considerations, are becoming a common cladding profile. Despite this observation, [1] doesn't offer any way to design by calculation these planks.

The closest shape to a plank that [1] is dealing with, are liner trays. Therefore, in a first part, we will use the formulas for the calculation of the resistance of such profiles. We will compare these results to the values obtained by the tests. Indeed, planks, like liner trays are large channel-type sections with two narrow flanges, two webs and one wide flange.

Another point that has to be studied, when a plank profile is designed is the possible dislocation of the joints. In a second part, we will propose an analytic method to evaluate the limit load regarding this criteria.

1. Moment resistance values

In the following formulas, the symbols used are defined as:

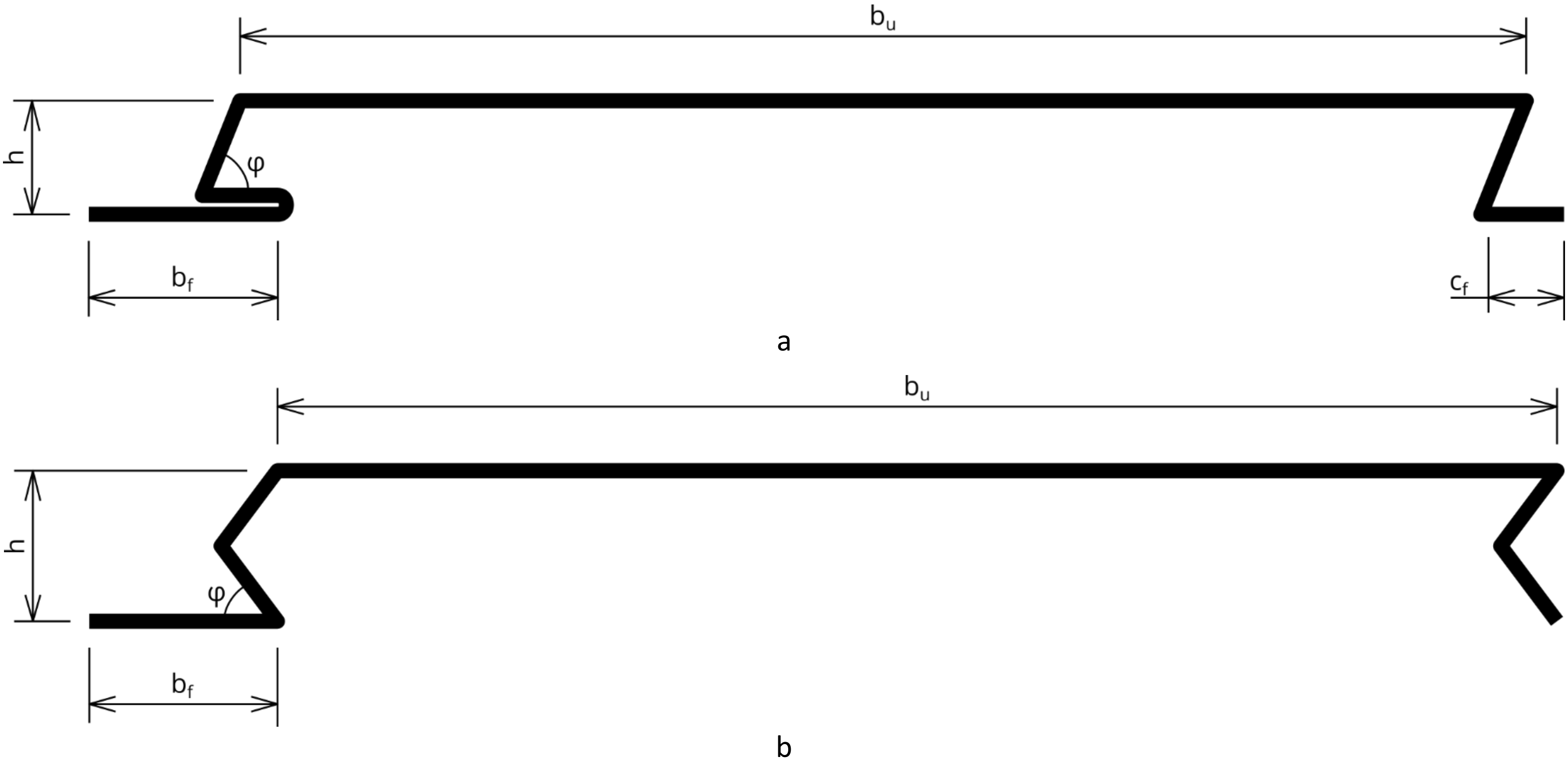

Figure 1 Symbols used in the formulas (a: clip joint; b: chevron joint)

1.1. Wide flange in compression (pressure)

According to [2], the effective part of the wide flange is:

$$b_{u,eff} = \rho_u \cdot b_u$$

Based on this effective width of the wide flange $b_{u,eff}$ and the fully effective webs and narrow flanges, we determine the centroid of the section.

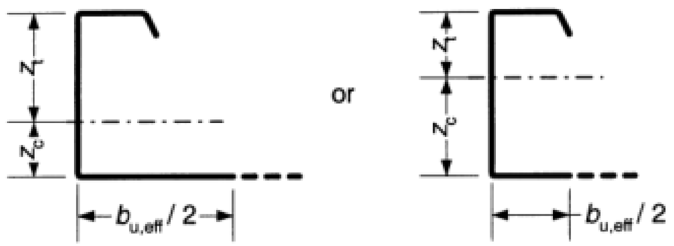

Figure 2 Centroid of the partly effective cross-section

The effective compressed height of the web, conforming to [2], is:

$$h_{eff} = \rho_w \cdot z_c$$

The moment resistance is thus determined, considering effective web and wide flange, using the formula (10.19) of [1]:

$$M_{c,Rd} = W_{eff} \cdot \frac{0.8 \cdot f_{yb}}{\gamma_{M0}}$$

With:

$$W_{eff} = \min\left(\frac{I_{y,eff}}{z_{c,eff}}; \frac{I_{y,eff}}{z_{t,eff}}\right)$$

1.2. Wide flange in tension (suction)

According to § 10.2.2.2 of [1], the centroid of the gross section is determined. The effective width of the wide flange is calculated

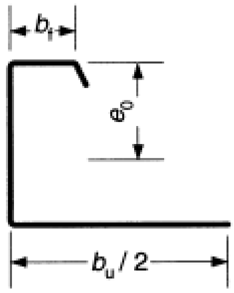

Figure 3 Centroid of the gross section

Therefore, the effective width of the wide flange is calculated using the following formula:

$$b_{u,eff} = \frac{53.3 \cdot 10^{10} \cdot {e_0}^2 \cdot t^4}{h \cdot L \cdot {b_u}^3}$$

The effective widths of the narrow flanges are evaluated according to [2]:

$$\begin{cases} b_{f,eff} = \rho_b \cdot b_f \\ c_{f,eff} = \rho_c \cdot c_f \end{cases}$$

Based on this effective widths of the flanges $b_{u,eff}$, $b_{f,eff}$, $c_{f,eff}$ and the fully effective webs, we determine the centroid of the section.

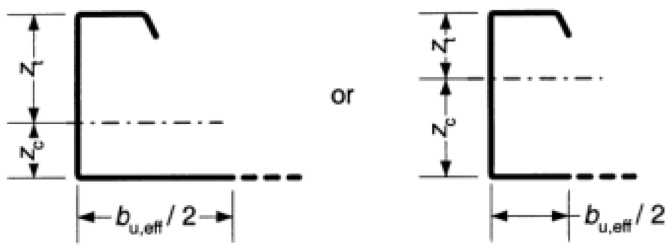

Figure 4 Centroid of the partly effective cross-section

As before, effective compressed part of the web, conforming to [2], is:

$$h_{eff} = \rho_w \cdot z_c$$

As previously, the moment resistance is thus determined, considering effective web and flanges, using the formula (10.19) of [1]:

$$M_{b,Rd} = W_{eff} \cdot \frac{0.8 \cdot f_{yb}}{\gamma_{M0}}$$

With:

$$W_{eff} = \min\left(\frac{I_{y,eff}}{z_{c,eff}}; \frac{I_{y,eff}}{z_{t,eff}}\right)$$

2. End support resistance value

According to §6.1.7.3 of [1], the end support resistance is determined by:

$$R_{w,Rd} = \frac{\alpha \cdot t^2 \cdot \sqrt{f_{yb} \cdot E} \cdot \left(1 - 0.1 \cdot \sqrt{\frac{r}{t}}\right) \cdot \left(0.5 + \sqrt{0.02 \cdot \frac{l_a}{t}}\right) \cdot \left[2.4 + \left(\frac{\varphi}{90}\right)^2\right]}{\gamma_{M1}}$$

With:

- $\alpha = 0.115$
- $l_a = 10\ mm$

3. Non-dislocation of the planks

The non-dislocation of the planks is verified limiting the displacement of the joint. The displacement of the joint is determined evaluating two components, a vertical one and a horizontal one. We then combine these values and compare them to the maximum acceptable displacement.

3.1. Vertical displacement

Due to the transmission of the load $2.u$, the small flange is deformed (The load here is 2.u because this displacement is linked to the total width of a plank, not only a half width). Due to the horizontal deformation of the plank, the small flange is embed on the side of the joint.

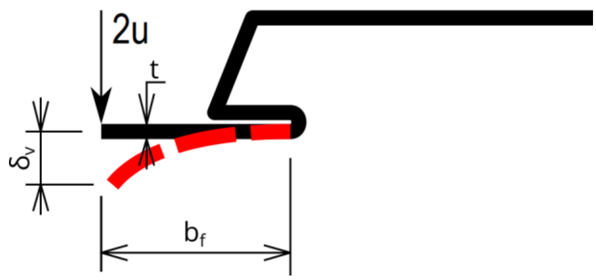

Figure 5 Vertical displacement of the small flange

To evaluate the vertical displacement, we can study the following mechanical model:

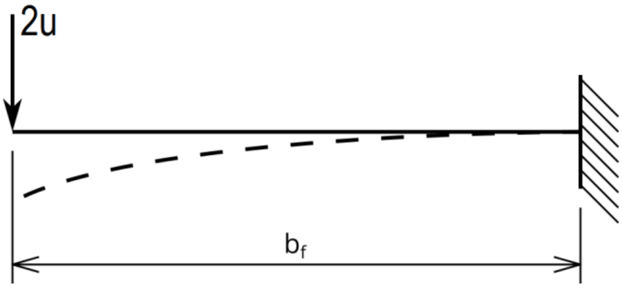

Figure 6 Embedded beam with a local load

This vertical displacement due to the application of the load, is:

$$\delta_v = \frac{2 \cdot u \cdot {b_f}^3}{3 \cdot E \cdot I}$$

With:

$$I = \frac{1{,}000 \cdot t^3}{12 \cdot (1 - \nu^2)}$$

3.2. Horizontal displacement

The horizontal displacement can be decomposed in two different components.

The first component is due to the embedment moment that results from the lockage of the joint.

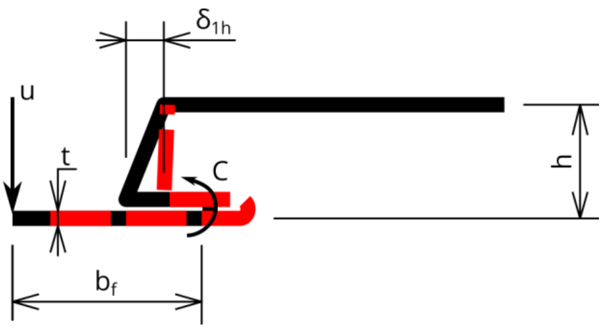

Figure 7 Horizontal displacement

To evaluate this displacement, we can study the following mechanical model:

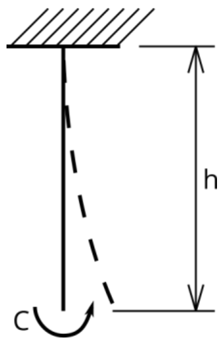

Figure 8 Embedded beam with a torque

In this case, the horizontal displacement δ_{1h} due to this behaviour, is:

$$\delta_{1h} = \frac{C \cdot h^2}{2 \cdot E \cdot I}$$

With:

$$C = u \cdot b_f$$
$$I = \frac{1{,}000 \cdot t^3}{12 \cdot (1 - \nu^2)}$$

The second component of this horizontal displacement is caused by the transversal deformation of the plank:

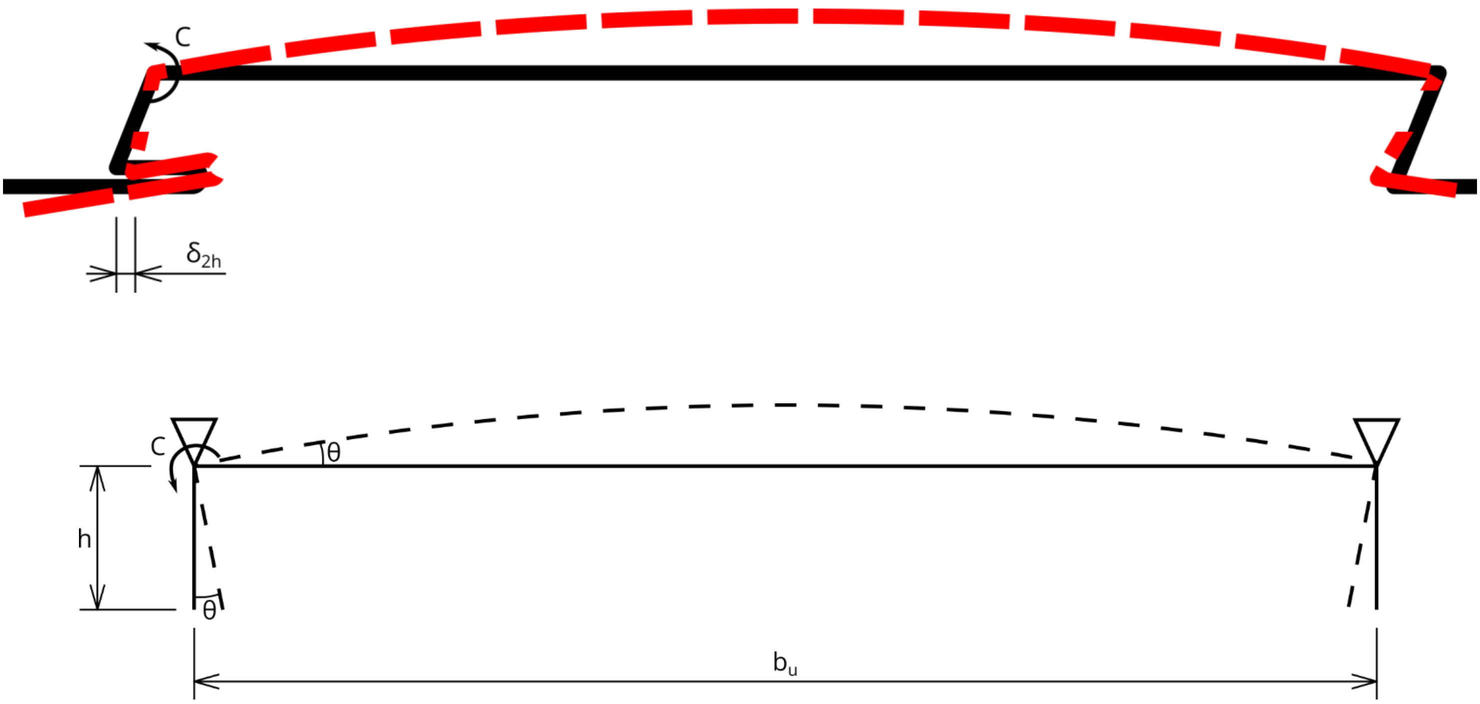

Figure 9 Isostatic beam with a torque

In order to calculate this component, the plank can be modelled as follows:

Based on the previous calculated torque C, we can deduct:

$$\theta = \frac{C \cdot b_u}{3 \cdot E \cdot I}$$

Where:

$$I = \frac{1{,}000 \cdot t^3}{12 \cdot (1 - \nu^2)}$$

Thereafter, we can conclude:

$$\tan\theta = \frac{\delta_{2h}}{h} = \theta \quad \Rightarrow \quad \delta_{2h} = \theta \cdot h = \frac{C \cdot b_u \cdot h}{3 \cdot E \cdot I}$$

Combining the two components of the horizontal displacement, we conclude:

$$\delta_h = \delta_{1h} + \delta_{2h} = u \cdot b_f \cdot \frac{12 \cdot (1 - \nu^2)}{E \cdot 1{,}000 \cdot t^3} \cdot \left(\frac{b_u \cdot h}{3} + \frac{h^2}{2}\right)$$

3.3. Total displacement

The total displacement is determined combining the two previously evaluated components:

$$\delta = \sqrt{{\delta_v}^2 + {\delta_h}^2}$$

In the above formulas, the u load, based on the distributed load q is:

$$u = \frac{1}{2} \cdot q \cdot b_u$$

This displacement has to be inferior to the limit displacement:

$$\delta \leq \delta_{\mathrm{lim}}$$

Where:

$$\delta_{\mathrm{lim}} = \begin{cases} c_f & \text{for clip joints} \\ \dfrac{h}{2 \cdot \tan\varphi} & \text{for chevron joints} \end{cases}$$

3.4. Maximum load

Based on the overhead formulas, we can calculate the maximum load to avoid dislocation:

$$\delta = \sqrt{{\delta_v}^2 + {\delta_h}^2} = \sqrt{\left[\frac{2 \cdot u \cdot {b_f}^3}{3} \cdot \frac{12 \cdot (1 - \nu^2)}{E \cdot 1{,}000 \cdot t^3}\right]^2 + \left[u \cdot b_f \cdot \frac{12 \cdot (1 - \nu^2)}{E \cdot 1{,}000 \cdot t^3} \cdot \left(\frac{b_u \cdot h}{3} + \frac{h^2}{2}\right)\right]^2}$$

$$= \sqrt{\left[u \cdot \frac{12 \cdot (1 - \nu^2)}{E \cdot 1{,}000 \cdot t^3}\right]^2 \cdot \left[\left(\frac{2 \cdot {b_f}^3}{3}\right)^2 + \left(b_f \cdot \left(\frac{b_u \cdot h}{3} + \frac{h^2}{2}\right)\right)^2\right]}$$

$$= u \cdot \frac{12 \cdot (1 - \nu^2)}{E \cdot 1{,}000 \cdot t^3} \cdot \sqrt{\left(\frac{2 \cdot {b_f}^3}{3}\right)^2 + \left[b_f \cdot \left(\frac{b_u \cdot h}{3} + \frac{h^2}{2}\right)\right]^2}$$

Considering $\delta \leq \delta_{\mathrm{lim}}$, we can deduct that:

$$\delta_{\mathrm{lim}} = u_{\max} \cdot \frac{12 \cdot (1 - \nu^2)}{E \cdot 1{,}000 \cdot t^3} \cdot \sqrt{\left(\frac{2 \cdot {b_f}^3}{3}\right)^2 + \left[b_f \cdot \left(\frac{b_u \cdot h}{3} + \frac{h^2}{2}\right)\right]^2}$$

$$\Rightarrow u_{\max} = \frac{E \cdot 1{,}000 \cdot t^3 \cdot \delta_{\mathrm{lim}}}{12 \cdot (1 - \nu^2) \cdot \sqrt{\left(\frac{2 \cdot {b_f}^3}{3}\right)^2 + \left[b_f \cdot \left(\frac{b_u \cdot h}{3} + \frac{h^2}{2}\right)\right]^2}}$$

We can therefore conclude that:

$$q_{\max} = \frac{2 \cdot u_{\max}}{b_u}$$

4. Comparison between theoretical and test values

Based on the formulas developed above, we can deduct the theoretical resistance values and compare them to the test value, obtained in [3]

Profile	Nominal thick. t_{nom} mm	Moment resitance M_{Rd} kN·m/m		Difference
		Test	Calculation	
CLADEO 300	0.75	1.03	0.73	-29%
	1.00	1.87	1.19	-36%
ZEPHIR 300 without reinf.	0.75	1.24	0.91	-27%
	1.00	1.87	1.28	-32%
ZEPHIR 300 with reinf.	0.75	1.17	0.91	-22%
	1.00	1.97	1.28	-35%

Table 1 Single span pressure performances comparison

Profile	Nominal thick. t_{nom} mm	Moment resitance M_{Rd} kN·m/m		Difference
		Test	Calculation	
CLADEO 300	0.75	–	0.54	–
	1.00	1.96	0.88	-55%
ZEPHIR 300 without reinf.	0.75	1.15	0.57	-50%
	1.00	1.90	0.91	-52%
ZEPHIR 300 with reinf.	0.75	1.04	0.57	-45%
	1.00	1.87	0.91	-51%

Table 2 Single span suction performances comparison

Profile	Nominal thick. t_{nom} mm	Moment resitance M_{Rd} kN·m/m		Difference
		Test	Calculation	
CLADEO 300	0.75	1.15	0.73	-36%
	1.00	2.02	1.19	-41%
ZEPHIR 300 without reinf.	0.75	1.36	0.91	-33%
	1.00	2.22	1.28	-42%
ZEPHIR 300 with reinf.	0.75	1.37	0.91	-34%
	1.00	2.14	1.28	-40%

Table 3 Double span pressure performances comparison

Profile	Nominal thick. t_{nom} mm	Moment resitance M_{Rd} kN·m/m		Difference
		Test	Calculation	
CLADEO 300	0.75	1.22	0.54	-56%
	1.00	1.74	0.88	-49%
ZEPHIR 300 without reinf.	0.75	1.12	0.57	-49%
	1.00	1.30	0.91	-30%
ZEPHIR 300 with reinf.	0.75	1.03	0.57	-44%
	1.00	1.74	0.91	-47%

Table 4 Double span suction performances comparison

Profile	**Nominal thick. t_{nom}** mm	**Shear resitance F_{Rd}** kN·m/m		**Difference**
		Test	Calculation	
CLADEO 300	0.75	11.95	8.64	-28%
	1.00	22.90	14.79	-35%
ZEPHIR 300	0.75	9.49	8.18	-14%
	1.00	16.78	14.00	-17%

Table 5 End support performances comparison

Profile	**Nominal thick. t_{nom}** mm	**Non dislocation load q_{Rd}** kN/m²		**Difference**
		Test	Calculation	
CLADEO 300	0.75	4.97	4.81	-3%
	1.00	–	–	–
ZEPHIR 300	0.75	–	–	–
	1.00	6.88	6.98	1,5%

Table 6 Non dislocation performances comparison

Conclusion

The observation made in [3], that the bending moment performance of the profiles are the same whether it is isostatic or continuous, is coherent with the calculation method developed before. Indeed, we can see that the calculated values aren't influenced by the fact that the profiles is isostatic or continuous.

References

[1] CEN, EN 1993–1–3: Eurocode 3 – Design of steel structures – Part 1-3: General rule - Supplementary rules for cold-formed member and sheeting, 2006.

[2] CEN, EN 1993–1–5: Eurocode 3 – Design of steel structures – Part 1-5: Plated structural elements, 2006.

[3] M. BLANC, GRISPE – WP4: Calculation method for cladding systems – D4.4 Test analysis and interpretation, 2016.

Annex A: Calculation of resistance values for CLADEO 300

To simplify the calculation, we will consider a simplified version of the profile such as below.

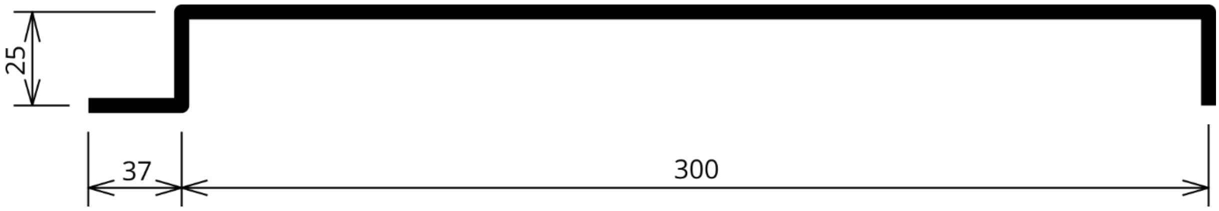

Figure 10 Simplified shape of CLADEO 300 used for calculation

The nominal characteristics of the material used in the further calculation are:

$$t = 0.75\ mm$$

$$f_{yb} = 320\ MPa \Rightarrow \varepsilon = \sqrt{\frac{235}{f_{yb}}} = 0.734$$

We study the following configuration:

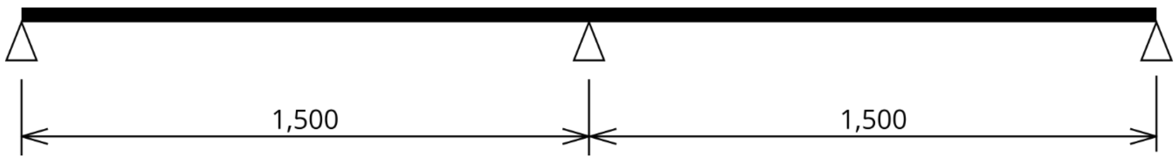

Figure 11 Configuration

A.1. Bending resistance

A.1.1. Pressure

The load direction is as following:

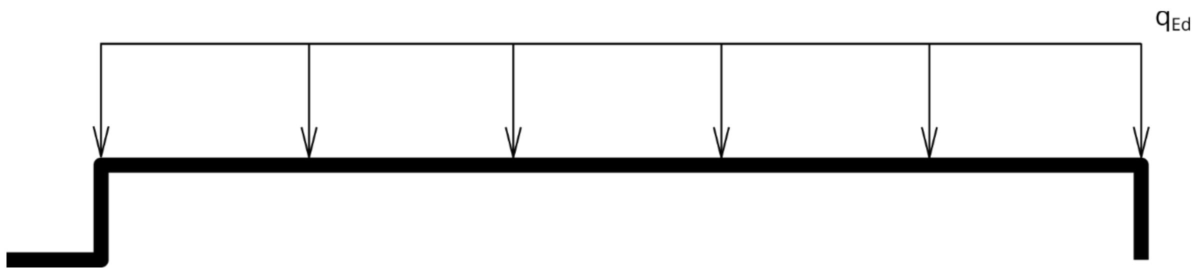

Figure 12 Pressure load direction

We first calculate the effective width of the large flange (uniformly compressed one) according to [2]:

$$\bar{\lambda}_{p,u} = \frac{b_u/_t}{28{,}4 \cdot \varepsilon \cdot \sqrt{k_\sigma}} = \frac{300/_{0.75}}{28.4 \times 0.734 \times \sqrt{4.0}} = 9.594$$

$$\bar{\lambda}_{p,u,lim} = 0.5 + \sqrt{0.085 - 0.055 \cdot \psi_u} = 0.5 + \sqrt{0.085 - 0.055 \times 1.0} = 0.673$$

For an internal compression element:

$$\bar{\lambda}_{p,u} > \bar{\lambda}_{p,u,lim} \Rightarrow \rho_u = \frac{\bar{\lambda}_{p,u} - 0.055 \cdot (3 + \psi_u)}{\bar{\lambda}_{p,u}^{\ 2}} = \frac{9.594 - 0.055 \cdot (3 + 1.0)}{9.594^2} = 0.102$$

Therefore, the effective width of the large flange is:

$$b_{u,eff} = \rho_u \cdot b_u = 0.102 \times 300 = 30.6\, mm$$

$$b_{e,u} = 0{,}5 \cdot b_{eff,u} = 0.5 \times 30.6 = 15.3\, mm$$

We determine the centroid of the following section:

Figure 13 Effective profile regarding local buckling of the compressed flange in pressure

Section #		l mm	h mm	z mm	l·z mm²	l·z² mm³	I_part/t mm⁴
left wing	1	37.0	0.75	25.0	925.00	23,125.00	0.000
	2	25.0	25.0	12.5	312.50	3,906.25	1,302.083
	3	15.3	0.75	0.0	0.00	0.00	0.000
right wing	4	15.3	0.75	0.0	0.00	0.00	0.000
	5	25.0	25.0	12.5	312.50	3,906.25	1,302.083
Σ		**117.6**	–	–	**1,550.00**	**30,937.50**	**2,604.166**

Table 7 Properties of the sections

The position of the neutral axis of the section in Figure 13 is:

$$z_c = \frac{\sum l \cdot z}{\sum l} = \frac{1{,}550.00}{117.6} = 13.2\, mm$$

$$z_t = h - z_c = 25.0 - 13.2 = 11.8\, mm$$

Now, we can evaluate the effectiveness of the webs, according to [2]:

$$\psi_w = -\frac{z_t}{z_c} = -\frac{11.8}{13.2} = -0.894$$

$$k_\sigma = 7.81 - 6.29 \cdot \psi + 9.78 \cdot \psi^2 = 7.81 - 6.29 \times (-0.894) + 9.78 \times (-0.894)^2 = 21.25$$

$$\bar{\lambda}_{p,w} = \frac{h/_t}{28{,}4 \cdot \varepsilon \cdot \sqrt{k_\sigma}} = \frac{25/_{0.75}}{28.4 \times 0.734 \times \sqrt{21.25}} = 0.347$$

$$\bar{\lambda}_{p,w,lim} = 0.5 + \sqrt{0.085 - 0.055 \cdot \psi_w} = 0.5 + \sqrt{0.085 - 0.055 \times (-0.894)} = 0.866$$

The reduction ratio is:

$$\bar{\lambda}_{p,w} < \bar{\lambda}_{p,w,lim} \Rightarrow \rho_w = 1.0$$

The web is fully effective.

The effective inertia for one plank is:

$$I_{eff,pl} = t \cdot \left(\sum l \cdot z^2 + \sum \frac{I_{part}}{t} - {z_c}^2 \cdot \sum l\right) = 0.75 \times (30{,}937.50 + 2604.166 - 13.2^2 \times 117.6) = 9788.28\ mm^4$$

We can generalize:

$$I_{eff} = I_{eff,pl} \cdot \frac{1000}{b_u} = 9788.28 \times \frac{1000}{300} = 32{,}627.61\ {}^{mm^4}/_{m}$$

$$W_{eff} = \frac{I_{eff}}{\max(z_c; z_t)} = \frac{32{,}627.61}{13.2} = 2{,}471.79\ {}^{mm^3}/_{m}$$

We can deduct the moment resistance:

$$M_{c,Rd} = W_{eff} \cdot \frac{0.8 \cdot f_{yb}}{\gamma_{M0}} = 2{,}471.79 \times \frac{0.8 \times 320}{1.0} = 632{,}778.24\ {}^{N \cdot mm}/_{m} \quad \text{i.e.} \quad 0.633\ {}^{kN \cdot m}/_{m}$$

A.1.2. Suction

The load direction is as following:

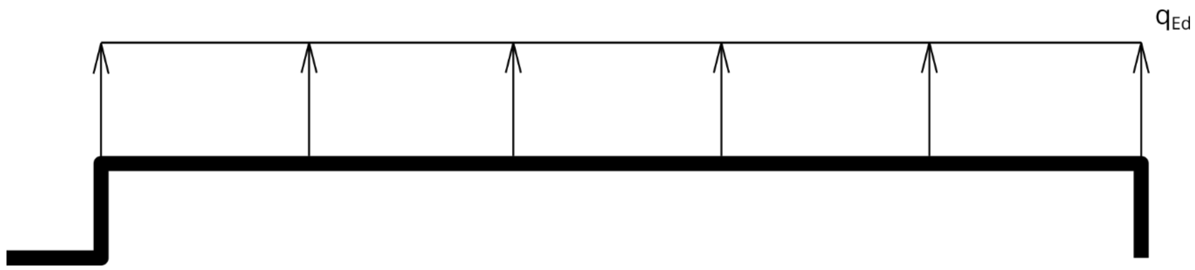

Figure 14 Suction load direction

The initial centroid of the gross section:

$$e_0 = \frac{\sum l \cdot z}{\sum l} = \frac{37.0 \times 25.0 + 25.0 \times 12.5 + 300.0 \times 0.0 + 25.0 \times 12.5}{37.0 + 25.0 + 300.0 + 25.0} = 21.0\,mm$$

The effective width of the large flange according to [1] is:

$$b_{u,eff} = \frac{53.3 \cdot 10^{10} \cdot {e_0}^2 \cdot t^4}{h \cdot L \cdot {b_u}^3} = \frac{53.3 \times 10^{10} \times 21.0^2 \times 0.75^4}{25.0 \times 1{,}500.0 \times 300.0^3} = 73.5\,mm$$

$$b_{e,u} = 0{,}5 \cdot b_{eff,u} = 0.5 \times 73.5 = 36.8\,mm$$

We calculate the effective width of the small flange (uniformly compressed one) according to [2]:

$$\bar{\lambda}_{p,b} = \frac{{b_u}/{t}}{28{,}4 \cdot \varepsilon \cdot \sqrt{k_\sigma}} = \frac{{300}/{0.75}}{28.4 \times 0.734 \times \sqrt{4.0}} = 9.594$$

$$\bar{\lambda}_{p,u,lim} = 0.5 + \sqrt{0.085 - 0.055 \cdot \psi_u} = 0.5 + \sqrt{0.085 - 0.055 \times 1.0} = 0.673$$

For an internal compression element:

$$\bar{\lambda}_{p,u} > \bar{\lambda}_{p,u,lim} \Rightarrow \rho_u = \frac{\bar{\lambda}_{p,u} - 0.055 \cdot (3 + \psi_u)}{{\bar{\lambda}_{p,u}}^2} = \frac{9.594 - 0.055 \cdot (3 + 1.0)}{9.594^2} = 0.102$$

Therefore, the effective width of the large flange is:

$$b_{u,eff} = \rho_u \cdot b_u = 0.102 \times 300 = 30.6\,mm$$

$$b_{e,u} = 0{,}5 \cdot b_{eff,u} = 0.5 \times 30.6 = 15.3\,mm$$

We first calculate the effective width of the large flange (uniformly compressed one) according to [2]:

$$\bar{\lambda}_{p,u} = \frac{{b_u}/{t}}{28{,}4 \cdot \varepsilon \cdot \sqrt{k_\sigma}} = \frac{{300}/{0.75}}{28.4 \times 0.734 \times \sqrt{4.0}} = 9.594$$

$$\bar{\lambda}_{p,u,lim} = 0.5 + \sqrt{0.085 - 0.055 \cdot \psi_u} = 0.5 + \sqrt{0.085 - 0.055 \times 1.0} = 0.673$$

For an internal compression element:

$$\bar{\lambda}_{p,u} > \bar{\lambda}_{p,u,lim} \Rightarrow \rho_u = \frac{\bar{\lambda}_{p,u} - 0.055 \cdot (3 + \psi_u)}{{\bar{\lambda}_{p,u}}^2} = \frac{9.594 - 0.055 \cdot (3 + 1.0)}{9.594^2} = 0.102$$

Therefore, the effective width of the large flange is:

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$$b_{e,u} = 0{,}5 \cdot b_{eff,u} = 0.5 \times 30.6 = 15.3\,mm$$

We determine the centroid of the following section:

Figure 15 Effective profile regarding local buckling of the compressed flange in pressure

Section #		l mm	h mm	z mm	l·z mm²	l·z² mm³	I_{part}/t mm⁴
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	2	25.0	25.0	12.5	312.50	3,906.25	1,302.083
	3	15.3	0.75	0.0	0.00	0.00	0.000
right wing	4	15.3	0.75	0.0	0.00	0.00	0.000
	5	25.0	25.0	12.5	312.50	3,906.25	1,302.083
Σ		**117.6**	–	–	**1,550.00**	**30,937.50**	**2,604.166**

Table 8 Properties of the sections

The position of the neutral axis of the section in Figure 15 is:

$$z_c = \frac{\sum l \cdot z}{\sum l} = \frac{1{,}550.00}{117.6} = 13.2\ mm$$

$$z_t = h - z_c = 25.0 - 13.2 = 11.8\ mm$$

Now, we can evaluate the effectiveness of the webs, according to [2]:

$$\psi_w = -\frac{z_t}{z_c} = -\frac{11.8}{13.2} = -0.894$$

$$k_\sigma = 7.81 - 6.29 \cdot \psi + 9.78 \cdot \psi^2 = 7.81 - 6.29 \times (-0.894) + 9.78 \times (-0.894)^2 = 21.25$$

$$\bar{\lambda}_{p,w} = \frac{h/t}{28{,}4 \cdot \varepsilon \cdot \sqrt{k_\sigma}} = \frac{25/0.75}{28.4 \times 0.734 \times \sqrt{21.25}} = 0.347$$

$$\bar{\lambda}_{p,w,lim} = 0.5 + \sqrt{0.085 - 0.055 \cdot \psi_w} = 0.5 + \sqrt{0.085 - 0.055 \times (-0.894)} = 0.866$$

The reduction ratio is:

$$\bar{\lambda}_{p,w} < \bar{\lambda}_{p,w,lim} \Rightarrow \rho_w = 1.0$$

The web is fully effective.

The effective inertia for one plank is:

$$I_{eff,pl} = t \cdot \left(\sum l \cdot z^2 + \sum \frac{I_{part}}{t} - {z_c}^2 \cdot \sum l\right) = 0.75 \times (30{,}937.50 + 2604.166 - 13.2^2 \times 117.6) = 9788.28\ mm^4$$

We can generalize:

$$I_{eff} = I_{eff,pl} \cdot \frac{1000}{b_u} = 9788.28 \times \frac{1000}{300} = 32{,}627.61\, {}^{mm^4}\!/_{m}$$

$$W_{eff} = \frac{I_{eff}}{\max(z_c; z_t)} = \frac{32{,}627.61}{13.2} = 2{,}471.79\, {}^{mm^3}\!/_{m}$$

We can deduct the moment resistance:

$$M_{c,Rd} = W_{eff} \cdot \frac{0.8 \cdot f_{yb}}{\gamma_{M0}} = 2{,}471.79 \times \frac{0.8 \times 320}{1.0}$$
$$= 632{,}778.24\, {}^{N \cdot mm}\!/_{m} \quad \text{i.e.} \quad 0.633\, {}^{kN \cdot m}\!/_{m}$$

A.2. End support resistance

The end support resistance is:

$$R_{w,Rd} = \frac{\alpha \cdot t^2 \cdot \sqrt{f_{yb} \cdot E} \cdot \left(1 - 0{,}1 \cdot \sqrt{\frac{r}{t}}\right) \cdot \left(0{,}5 + \sqrt{0{,}02 \cdot \frac{l_a}{t}}\right) \cdot \left[2{,}4 + \left(\frac{\varphi}{90}\right)^2\right]}{\gamma_{M1}}$$
$$= \frac{0.115 \times 0.75^2 \cdot \sqrt{320 \times 210{,}000} \cdot \left(1 - 0{,}1 \cdot \sqrt{\frac{2}{0.75}}\right) \cdot \left(0.5 + \sqrt{0.02 \cdot \frac{10}{0.75}}\right) \cdot \left[2.4 + \left(\frac{90}{90}\right)^2\right]}{1.0}$$
$$= 8{,}202.88\, {}^{N}\!/_{m} \quad \text{i.e.} \quad 8.203\, {}^{kN \cdot m}\!/_{m}$$

A.3. Maximum load (non dislocation)

For CLADEO 300 (clip joint): $\delta_{\text{lim}} = 10\ mm$

The maximum load per web before dislocation of the joint is:

$$u_{\max} = \frac{E \cdot 1{,}000 \cdot t^3 \cdot \delta_{\text{lim}}}{12 \cdot (1 - \nu^2) \cdot \sqrt{\left(\frac{2 \cdot {b_f}^3}{3}\right)^2 + \left[b_f \cdot \left(\frac{b_u \cdot h}{3} + \frac{h^2}{2}\right)\right]^2}}$$
$$= \frac{210{,}000 \times 1{,}000 \times 0.75 \times 10}{12 \cdot (1 - 0{,}3^2) \cdot \sqrt{\left(\frac{2 \times 37^3}{3}\right)^2 + \left[37 \cdot \left(\frac{300 \times 25}{3} + \frac{25^2}{2}\right)\right]^2}}$$
$$= 1{,}318.33\, {}^{N}\!/_{m} \quad \text{i.e.} \quad 1.318\, {}^{kN}\!/_{m}$$

We can deduct that the uniform load applied on the plank is:

$$q_{\max} = \frac{2 \cdot u_{\max}}{b_u} = \frac{2 \times 1{,}318.33}{0.300} = 8{,}788.87\, {}^{N}\!/_{m^2} \quad \text{i.e.} \quad 8.789\, {}^{kN}\!/_{m^2}$$