GRISPE PLUS

VALORISATION OF KNOWLEDGE
FOR SPECIFIC PROFILED STEEL SHEETS

Liner Trays

Extension of the current design method according to EN 1993-1-3

The project has received financial support from the European Community (RFCS programme) under grant agreement No 754092.

Liner trays

- Typically used for inner sheets of wall systems
- Cold formed steel profile with wide flange, two webs and two narrow flanges
- Narrow flanges should be restrained by attached profiled steel sheeting
- Flanges and webs are reinforced with stiffeners
- Width: 500 - 600 mm
- Height: 90 - 240 mm

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Liner trays

- Application for hall-like buildings

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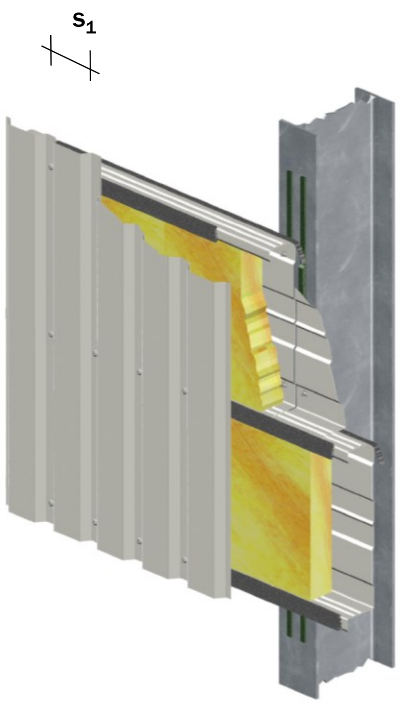
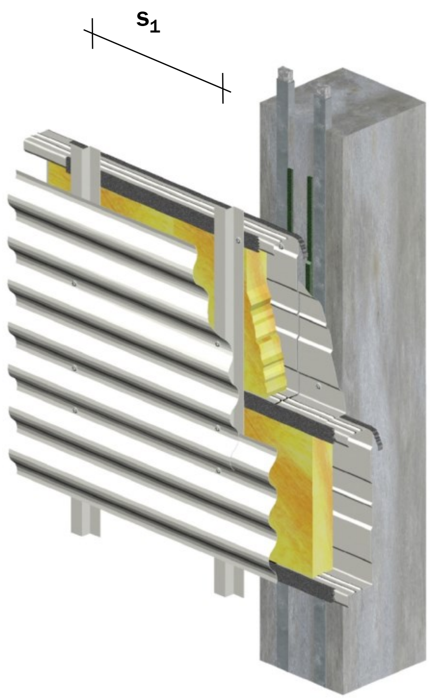
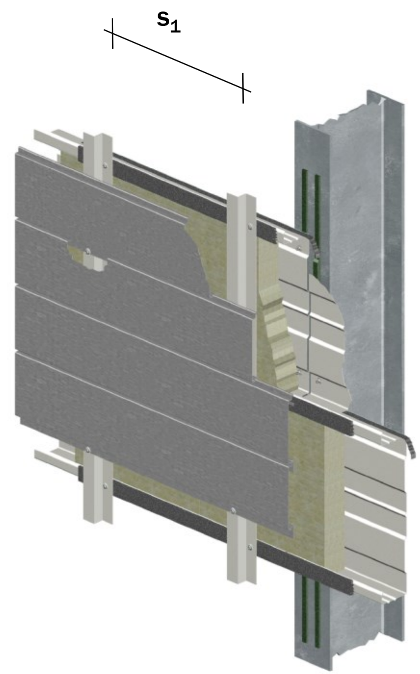
Liner tray wall systems

- Conventional solution with trapezoidal profile
- New solutions with distance profiles and sidings







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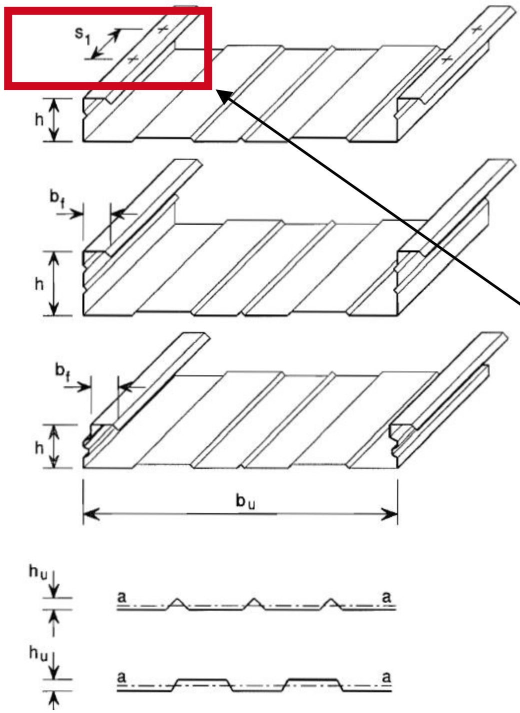
Design procedure according to EN 1993-1-3

- Chapter 10.2, Liner trays restrained by sheeting
  - Application range of liner trays



Source: Fig. 10.9 of the EN 1993-1-3

0,75 mm	$\leq$	t_{nom}	$\leq$	1,5 mm
30 mm	$\leq$	b_f	$\leq$	60 mm
60 mm	$\leq$	h	$\leq$	200 mm
300 mm	$\leq$	b_u	$\leq$	600 mm
		I_a/b_u	$\leq$	10 mm⁴/mm
		$\boxed{s_1}$	$\boxed{\leq}$	$\boxed{1000\ \text{mm}}$

Source: Tab. 10.6 of the EN 1993-1-3

Point of interest

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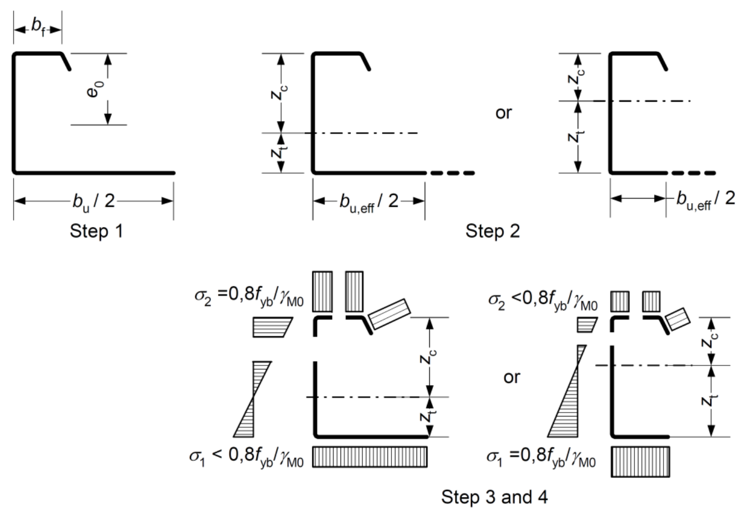
Design procedure according to EN 1993-1-3

- Chapter 10.2.2.2, Wide flange in tension

  - **Step 1:** Determine the centroid of the whole cross-section

  - **Step 2:** Determine the effective width of the wide flange $b_{u,eff}$



Source: Fig. 10.11 of the EN 1993-1-3

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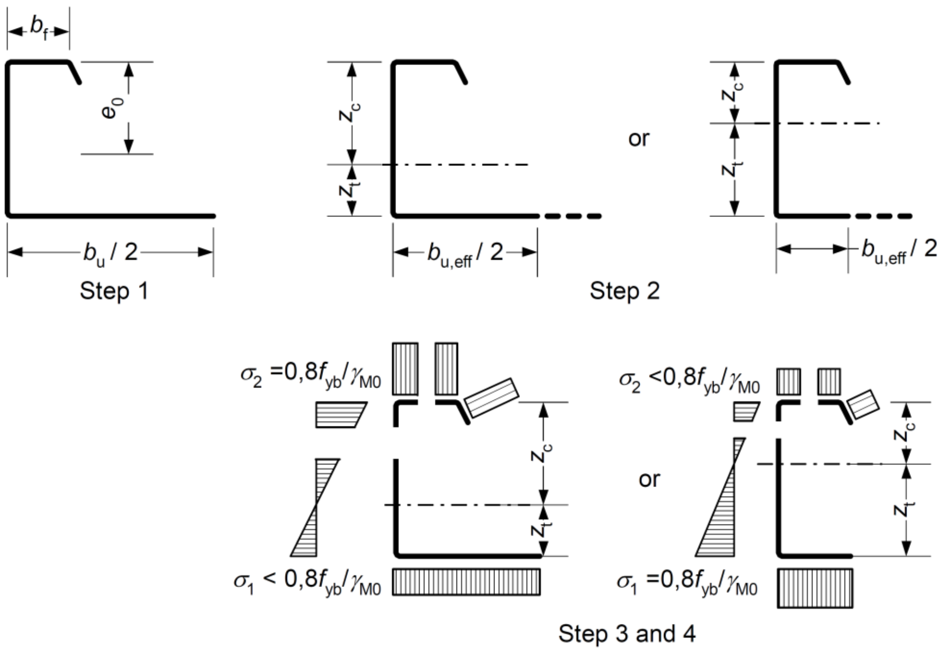
Design procedure according to EN 1993-1-3

- Chapter 10.2.2.2, Wide flange in tension

  - **Step 3:** Determine the effective areas of all the compression elements, based on values of the stress ratio $\psi = \sigma_2/\sigma_1$



Source: Fig. 10.11 of the EN 1993-1-3

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Introduction

Design procedure according to EN 1993-1-3

- Chapter 10.2.2.2, Wide flange in tension

  - **Step 4:** Determine the centroid of the effective cross-section and the moment resistance $M_{b,Rd}$:

$$M_{b,Rd} = 0{,}8 \cdot \boxed{\beta_b} \cdot W_{eff,com} \cdot f_{yb}/\gamma_{M0}$$

with

$$W_{eff,com} = I_{y,eff}/z_c$$

$$W_{eff,3} = I_{y,eff}/z_t$$

in which the correlation factor β_b is given:

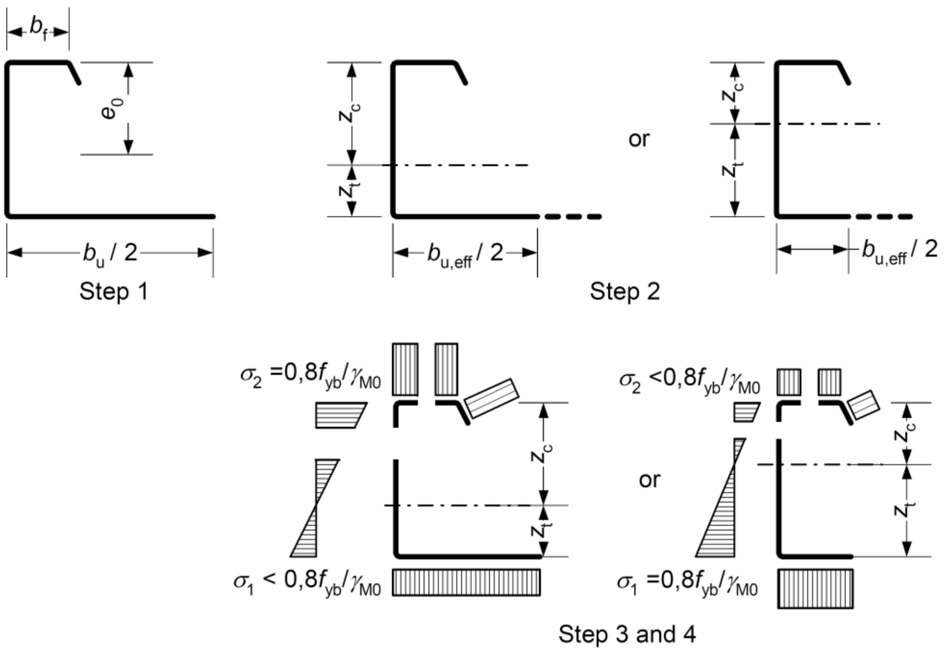
If $s_1 \leq 300$ mm

$$\beta_b = 1{,}0$$

If 300 mm $\leq s_1 \leq 1000$ mm:

$$\beta_b = 1{,}15 - s_1/2000$$

Source: EN 1993-1-3



Source: Fig. 10.11 of the EN 1993-1-3

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Design by testing according to EN 1993-1-3

- ANNEX A.2 Tests on profiled sheets and liner trays
  - 4 types of tests
    1) Single span test
    2) Double span test
    3) Internal support test
    4) End support test

- In Germany, there are additions to the test procedures according to EN 1993-1-3 and DIN 18807-2:
  - „Supplementary test principles for liner tray profiles“

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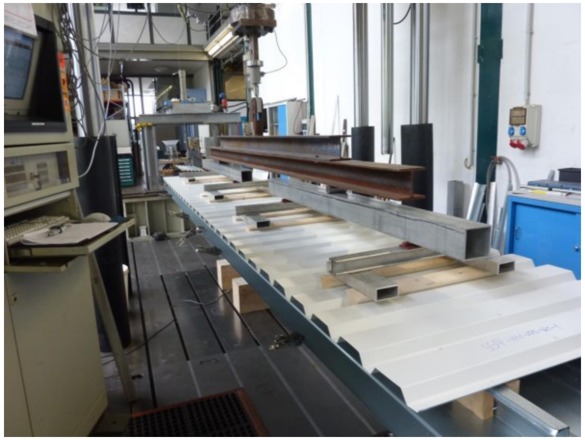
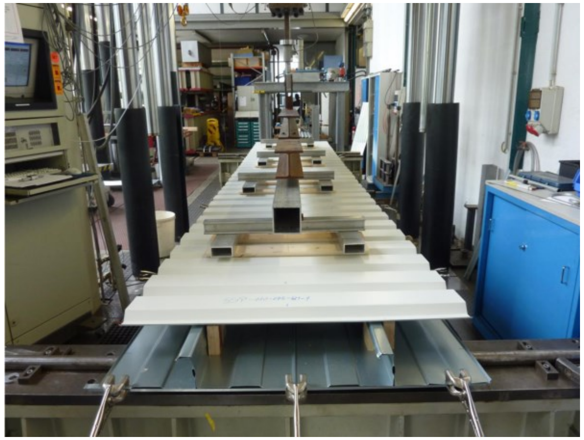
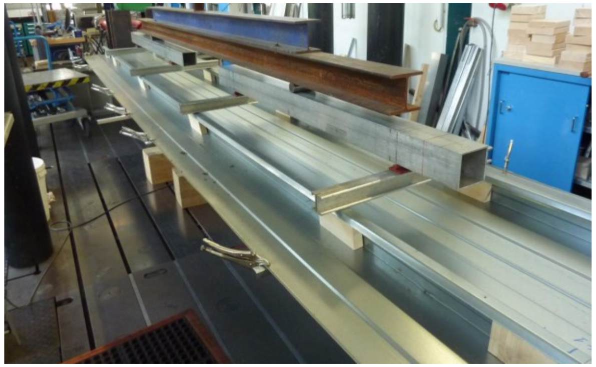
Test results of the GRISPE project







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Test results of the GRISPE project

<table>
<tr><th>Profile</th><th>Test</th><th>Nominal thickness t_N [mm]</th><th>Span L [mm]</th><th>Fixation distance s_1 [mm]</th></tr>
<tr><td rowspan="8">Liner trays: 110/600 and 160/600 + Trapezoidal profile: 35/207-0.75</td><td rowspan="4">Single span test: pressing load</td><td rowspan="4">0.75 and 1.00</td><td rowspan="4">6000</td><td>621</td></tr>
<tr><td>1242</td></tr>
<tr><td>1863</td></tr>
<tr><td>> 6000 (without fixation)</td></tr>
<tr><td rowspan="4">Internal support test: lifting load</td><td rowspan="4">0.75 and 1.00</td><td rowspan="4">2000</td><td>621</td></tr>
<tr><td>1242</td></tr>
<tr><td>1863</td></tr>
<tr><td>> 2000 (without fixation)</td></tr>
</table>

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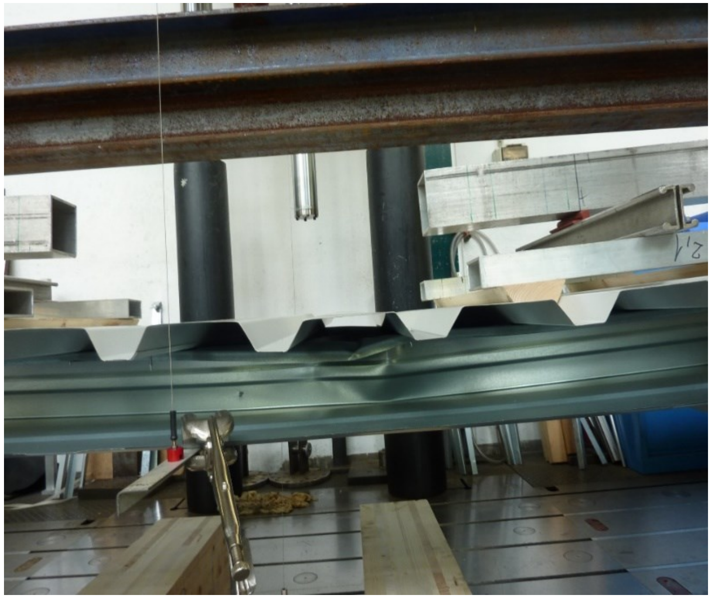
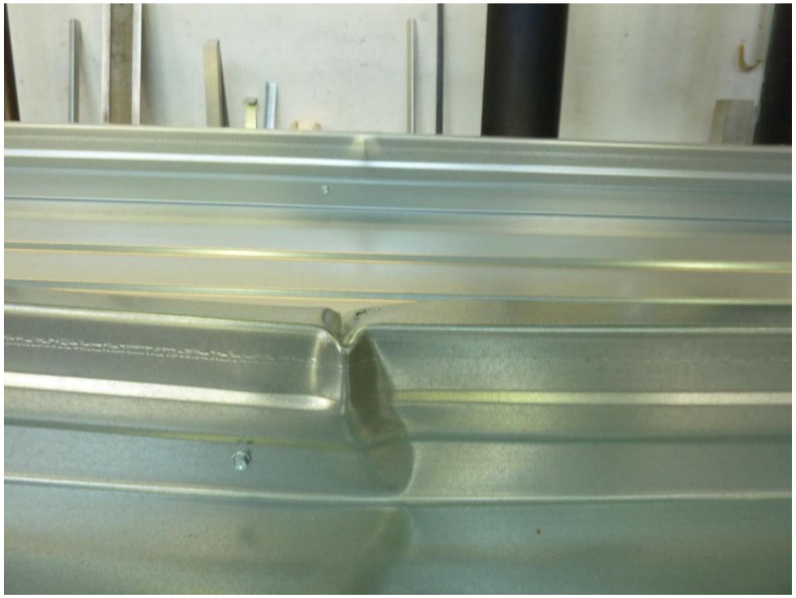
Test results of the GRISPE project

- Failure mode buckling of the upper flange in the middle of the span





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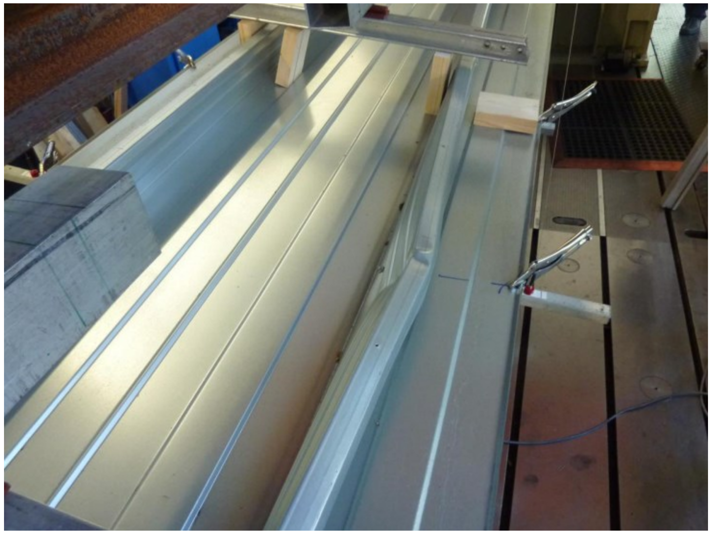
Test results of the GRISPE project

- Failure mode liner tray without outer cladding, load distribution in the lower flange



- Failure mode liner tray without outer cladding, load distribution in the upper flange, lateral buckling

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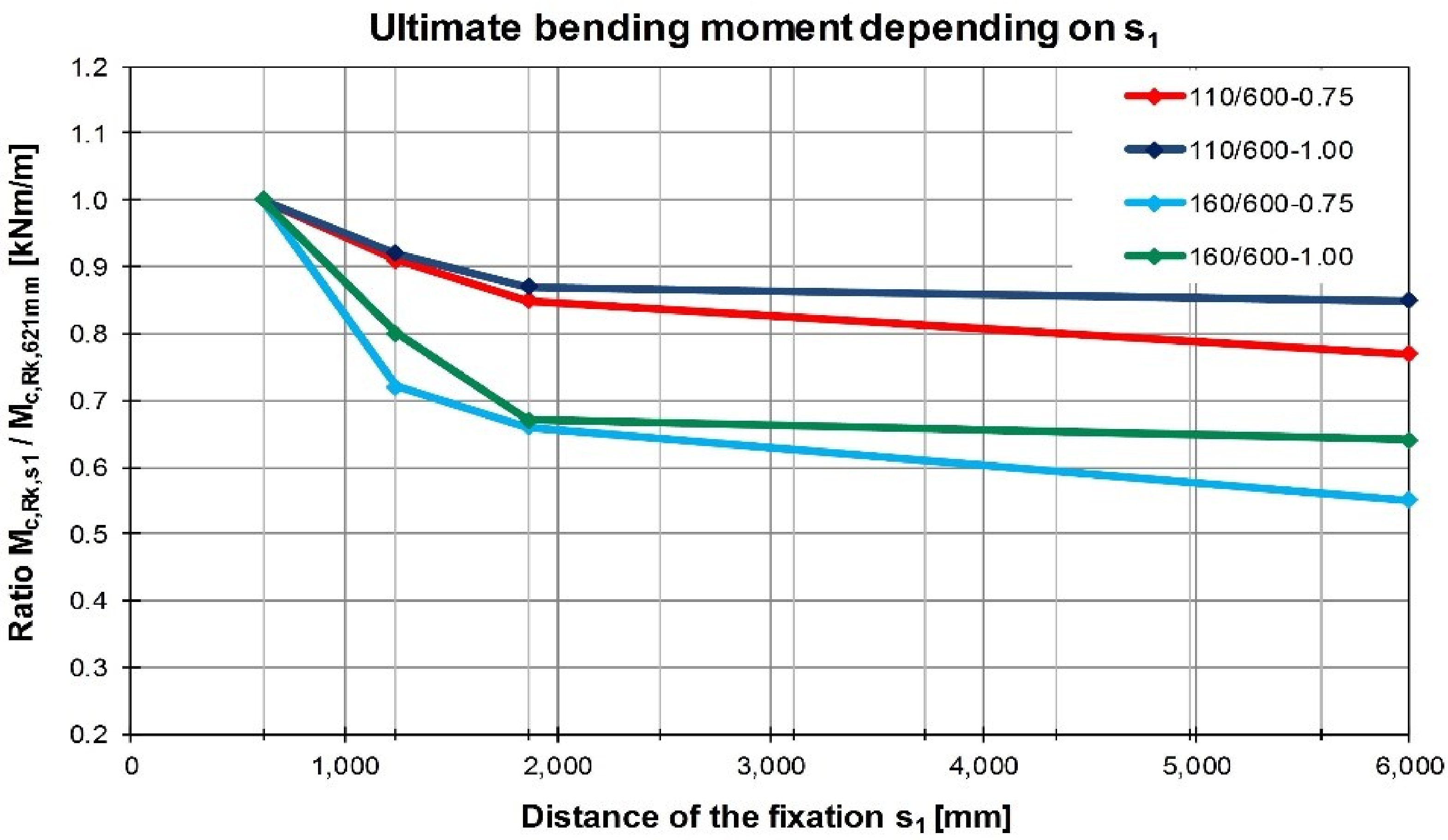
Test results of the GRISPE project



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Proposal for new design procedure for a fixing distance s_1 > 1000 mm

- Reason:
  - The actual design rule taking into account the effect of the fixing distance s_1 is rather conservative, and furthermore limited to a maximum fixing distance s_1 = 1000 mm.

- Subject:
  - Influence of the fixing distance s_1 on the bending moment capacity of liner trays
  - Improvement of the coefficient b_b and extension of the application range

→ Proposal for new calculation for b_b as a function of fixing distance s_1

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Proposal for new design procedure for a fixing distance s_1 > 1000 mm

- Ideas:
  - The ultimate positive bending moment is generally limited by the ultimate compression forces of the narrow flanges
  - The compressed flanges are stabilized against lateral buckling by the connections between liner tray and outer cladding
  - The ultimate bending moment is approximately proportional to the compression resistance of the narrow flanges
  - The reduction coefficient b_b to respect the fixing distance s_1 corresponds approximately to the reduction of the compression resistance of the narrow flanges

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Proposal for new design procedure for a fixing distance s_1 > 1000 mm

- Proposed change:
  - The (unknown) ultimate bending moment for a liner tray with the fixing distance $s_{1,2}$ (1000 mm < $s_{1,2} \leq$ 2000 mm) can be determined as follows:

$$M_{c,Rk,2} = \boxed{M_{c,Rk,1} \cdot \frac{N_{Rk,2}}{N_{Rk,1}}} = \boxed{M_{c,Rk,1} \cdot \beta_b}$$

  - with:
    - $M_{c,Rk,1}$: (already known) ultimate positive bending moment of the liner tray with a fixing distance $s_{1,1} \leq$ 1000 mm
    - $N_{Rk,1}$: characteristic compression force of the narrow flanges of the liner tray, calculated with the buckling length l = $s_{1,1}$
    - $N_{Rk,2}$: characteristic compression force of the narrow flanges of the liner tray, calculated with the buckling length l = $s_{1,2}$

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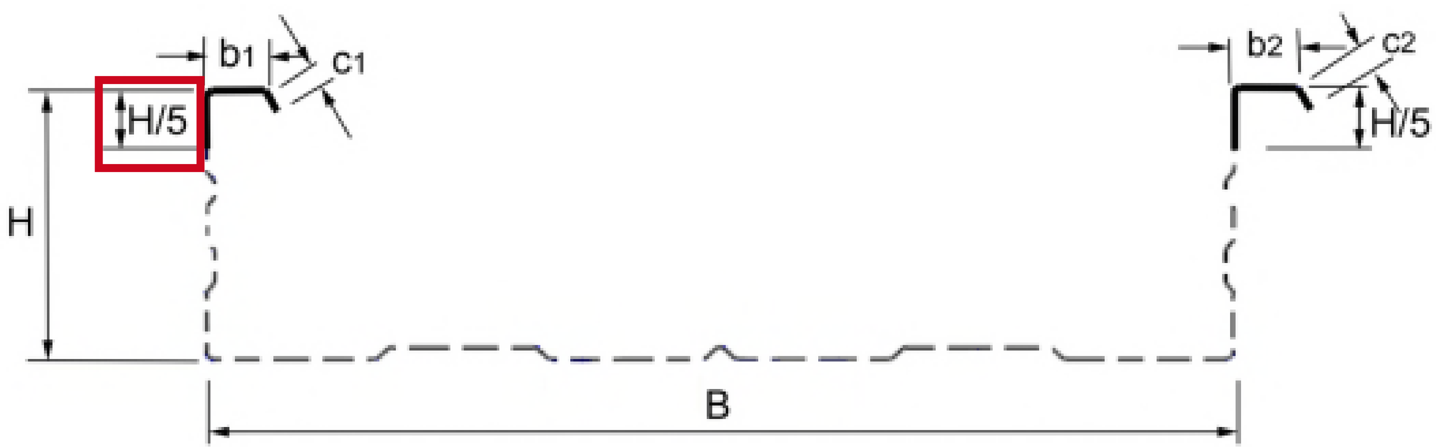
Proposal for new design procedure for a fixing distance s_1 > 1000 mm

- **Procedure:**
  - **Step 1:** Determination of the gross cross section of the compressed flanges



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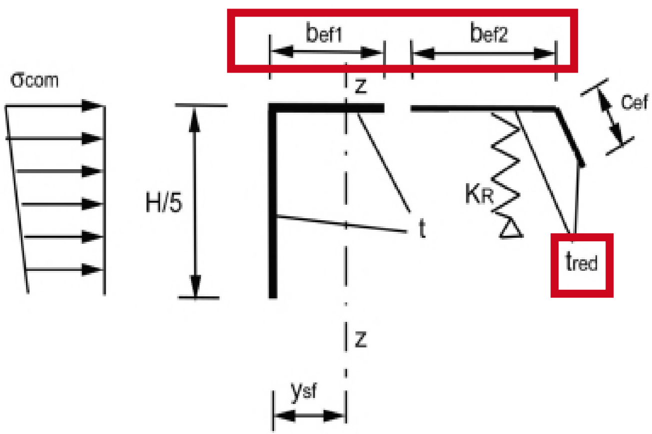
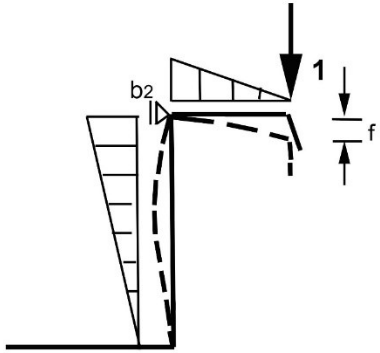
Proposal for new design procedure for a fixing distance s_1 > 1000 mm

- **Procedure:**
  - **Step 2:** Determination of the effective cross section of flanges





$$K_R = \frac{E \cdot t^3}{12 \cdot (1 - \mu^2)} \cdot \frac{3}{b_2 \cdot (b_2^2 + b_2 \cdot H)}$$

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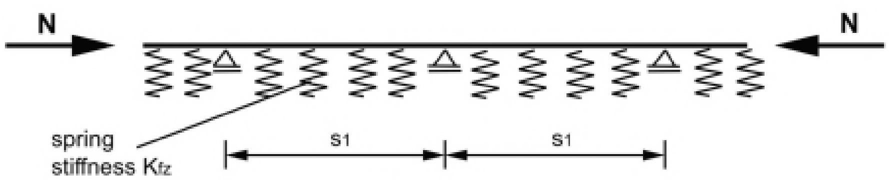
Proposal for new design procedure for a fixing distance s_1 > 1000 mm

- Procedure:
  - **Step 3:** Determination of the ultimate compression force of narrow flange with respect to lateral buckling

Elastically bedded beam under compression with respect to lateral buckling:



$$K_{fz} = \frac{E \cdot t^3}{12 \cdot (1 - \nu^2)} \cdot \frac{6}{2 \cdot h^3 + 3 \cdot b \cdot h^2}$$

Calculation of the critical axial force:

$$N_{cr} = \frac{n^2 \cdot \pi^2 \cdot E \cdot I_{fz}}{s_1^2} \cdot \frac{K_{fz} \cdot s_1^2}{n^2 \cdot \pi^2}$$

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Proposal for new design procedure for a fixing distance s_1 > 1000 mm

- Procedure:
  - **Step 3:** Determination of the ultimate compression force of narrow flange with respect to lateral buckling

Calculation of the characteristic compression forces $N_{Rk,i,s_{1,1}}$ and $N_{Rk,i,s_{1,2}}$ for the fixing distance $s_{1,1}$ and $s_{1,2}$:

$$N_{Rk} = \chi(a_0) \cdot A_{fz} \cdot f_{yb}$$

Iteration of the ultimate compressive stress:

$$\sigma_k = \chi(a_0) \cdot f_{yb}$$

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Proposal for new design procedure for a fixing distance s_1 > 1000 mm

- Procedure:
  - **Step 4:** Determination of the reduction coefficient b_b

The reduction coefficient b for the distance $s_{1,2}$ is thus calculated as follows:

$$\beta_b = \frac{N_{Rk,1,s_{1,2}} + N_{Rk,2,s_{1,2}}}{N_{Rk,1,s_{1,1}} + N_{Rk,2,s_{1,1}}}$$

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Design method

Summary

- Conventional liner tray wall systems do not fulfil the actual energy requirements.
- New solutions are developed for which no calculation methods are available in current regulations, or application boundaries of existing methods are exceeded.
- Within the scope of GRISPE, extensive experimental investigations have been performed on liner trays for fixing distances that are normatively not or insufficiently covered.
- Practicable calculation methods have been derived based on existing regulations and methods.

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