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GRISPE

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

STANDARDISATION BRIEF No 4

Liner trays

Due date: 30 June 2016
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Deliverable D 5.2 (4)

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

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	Dissemination Level	
PU	***Public***	
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ANNEXE 3

3.2 Proposed Amendments

AM-1-3-2016-04	
Subject	Influence of the fixing distance s_1 on the bending moment capacity of liner trays. Improvement of the coefficient β_b and extension of the application range
Clause No/ Subclause No/ Annex	10.2.2.3
Reason for Amendment	The actual design rule to take 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. Both aspects will be improved.
Proposed Change	The ultimate positive bending moment of the liner trays (wide flange in tension) is generally limited by the ultimate compression forces of the small flanges. The compressed flanges are stabilized against lateral buckling by the connections between liner tray and outer cladding; the fixing distance s_1 determines the buckling length of the compressed flange and therefore the ultimate compression forces of the small flanges and in consequence also the ultimate bending moment. The ultimate bending moment is approximately proportional to the compression resistance of the small flanges. The reduction coefficient β_b to respect the fixing distance s_1 corresponds approximately to the reduction of the compression resistance of the small flanges. Ultiamte bending moment $M_{c,\,Rk,2} = M_{c,Rk,1} * \frac{N_{R,k,2}}{N_{R,k,1}} = M_{c,Rk,1} * \beta_b$ with: $M_{c,Rk,1}$ (already known) ultimate positive bending moment of the liner trays for a fixing distance $s_{1,1}$ Design by calculation: The bending moment $M_{c,Rk,1}$ is the calculated ultimate bending moment for the fixing distance $s_{1,1}$ = 300 mm according to Clause 10.2.2.2 (β_b = 1,0) Design by testing: The bending moment $M_{c,Rk,1}$, which is determined by testing, is related to the distance $s_{1,1}$, which was chosen for the tests.

This fixing distance $s_{1,1}$ is mentioned in the technical documents of the liner tray (often: $s_1 = 621$ mm = 3 ribs of the cladding profile 35/307)

$M_{c,Rk,2}$ (unknown) ultimate positive bending moment of the liner trays for a fixing distance $s_{1,2}$
The bending moment $M_{c,Rk,2}$ is the recalculated ultimate bending moment for the interesting fixing distance $s_{1,2}$ .The interesting fixing distance $s_{1,2}$ corresponds to the foreseen fixing distance in a specific application.
The fixing distance $s_{1,2}$ should not exceed max $s_1 = 2000$ mm

$\beta_b = \frac{N_{R,k,2}}{N_{R,k,1}}$ reduction coefficient for fixing distances $s_1 \geq s_{1,1}$

$N_{R,k,1}$ characteristic compression force of the small flanges of the liner trays, calculated with the buckling length $l = s_{1,1}$

$N_{R,k,2}$ characteristic compression force of the small flanges of the liner trays, calculated with the buckling length $l = s_{1,2}$

The calculation of the characteristic compression force of the small flanges of the liner trays should respect the following principles:

- **Step 1:** Gross cross section of flanges
  The gross cross section of the compressed flange consists of the small flange, the edge stiffener and 1/5 of the web. Separate calculations should be executed for the small flanges on both sides of the liner tray, because the cross sections of both flanges are different.

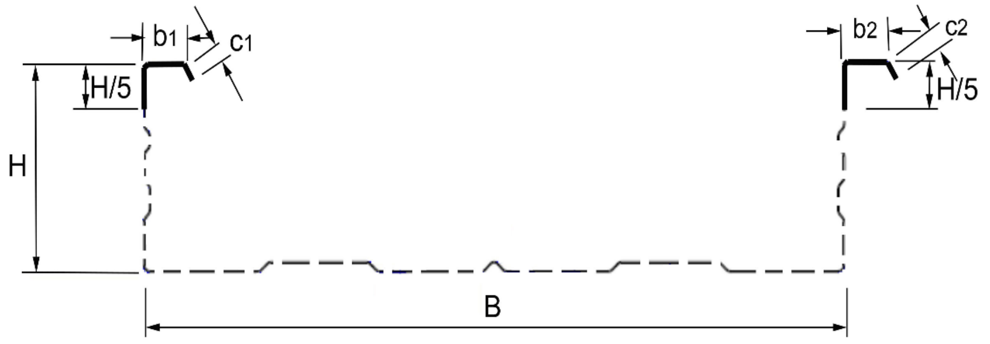

Fig nn: Liner tray, definition of the gross cross sections of the compressed flanges

- **Step 2:** Effective cross section of flanges

  The effective cross section should consider local buckling of flange (b_{ef1}, b_{ef2}) and the stiffener (c_{ef}) as well as buckling of the stiffener (t_{red}). The calculation is done for a chosen stress σ_{com} for both flanges of the liner tray.

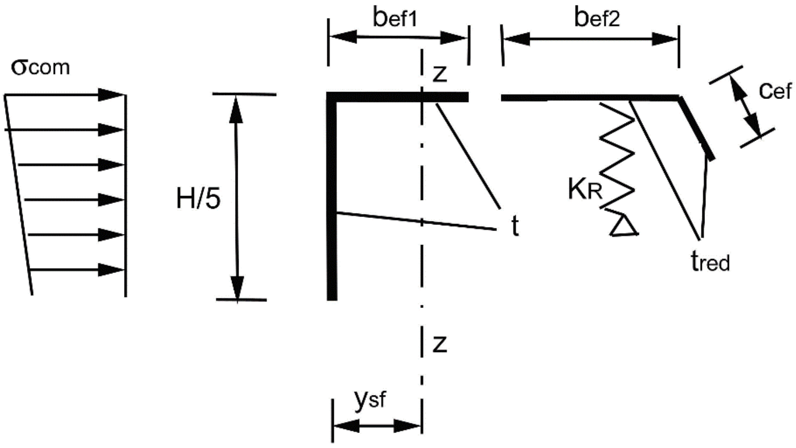

Fig nn: effective cross section of the compressed flange for a chosen stress σ_{com}.

Cross section values

y_{sf}	position of the neutral axis for lateral bending
A_{fz}	effective area of the compressed flange
J_{fz}	effective moment of inertia for bending about z-z-axis

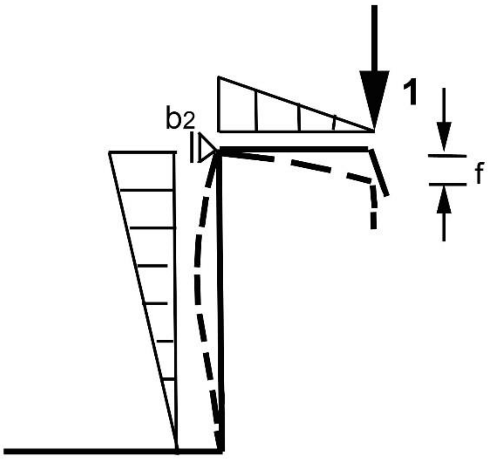

Fig nn: spring stiffness of the edge stiffener (shown for flange 2, analogue for flange 1) spring stiffness $$K_R = \frac{E * t^3}{12 * (1 - \mu^2)} * \frac{3}{b_2 * (b_2^2 + b_2 * H)}$$

- **Step 3:** Ultimate compression force of the small flange with respect to lateral buckling

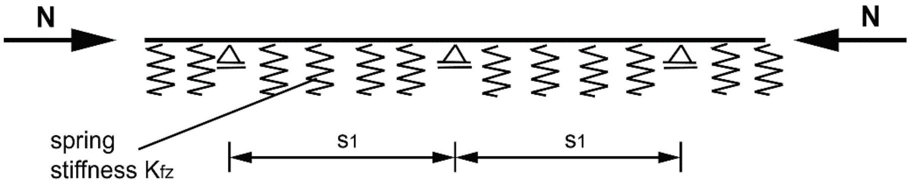

Fig nn: statical system of the compressed small flange of the liner tray

When considering lateral buckling of the compressed flange, the elastic foundation of the compressed flange in the lateral direction may be taken into account:

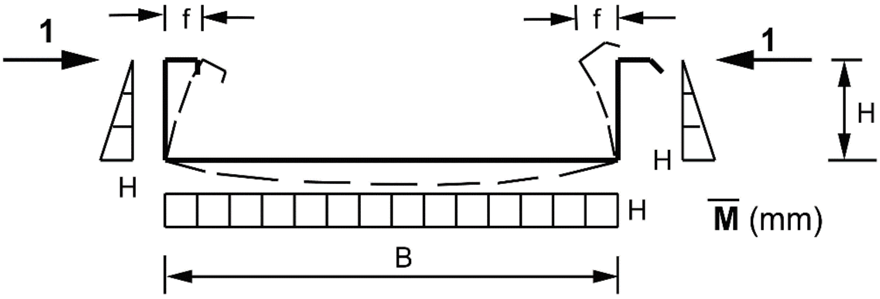

Fig nn: Moment distribution to calculate the spring stiffness K_{fz}

spring stiffness $$K_{fz} = \frac{E * t^3}{12 * (1 - \mu^2)} * \frac{6}{(2 * H^3 + 3 * B * H^2)}$$

critical axial force $$N_{cr} = \frac{n^2 * \pi^2 * E * J_{fz}}{s_1^2} + \frac{K_{fz} * s_1^2}{n^2 * \pi^2}$$

Normally, the axial force is a minimum for n = 1 (n = number of buckling waves between neighboured fixings).

The ultimate axial compression force N_{Rk} is calculated according to EN 1993-1-1 clause 6.3.1.1. Hereby, buckling curve a_0 may be used.

	ultimate axial force $N_{Rk} = \mathbf{X}(a_0) * N_{pl}$ $= \mathbf{X}(a_0) * A_{fz} * f_{yb}$ ultimate compressive stress $\boldsymbol{\sigma}_k = \mathbf{X}(a_0) * f_{yb}$ If $\boldsymbol{\sigma}_k$ is different from the initially chosen stress $\boldsymbol{\sigma}_{com}$, the calculation should be repeated from step 2 using $\boldsymbol{\sigma}_{com} = .\boldsymbol{\sigma}_k$ until the stress $\boldsymbol{\sigma}_{com}$, which is the basis for the effective cross section, and the buckling stress of the compressed flange $\boldsymbol{\sigma}_k$ have converged. Analogue calculations should be executed for both flanges of the liner tray. • **Step 4:** Reduction coefficient $\boldsymbol{\beta}_b$ The calculation according step 2 and step 3 is done for both flanges and for both fixing distances $s_{1,1}$ and $s_{1,2}$. The reduction coefficient for the fixing distance $s_{1,2}$ is $\boldsymbol{\beta}_b$ (distance $s_{1,2}$) $= [N_{Rk} (fl\ 1, s_{1,2}) + N_{Rk} (fl\ 2, s_{1,2})] / [N_{Rk} (fl\ 1, s_{1,1}) + N_{Rk} (fl\ 2, s_{1,1})]$
Background Information	[1] D2.5 Background and draft annexes for EN 1993-1-3 for liner trays, 31.10.2015, KIT