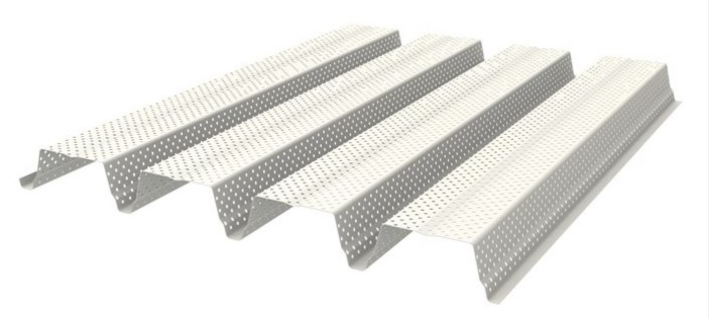
GRISPE PLUS

VALORISATION OF KNOWLEDGE FOR SPECIFIC PROFILED STEEL SHEETS

PERFORATED PROFILES



Anna PALISSON

Sources

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

Perforated profiles

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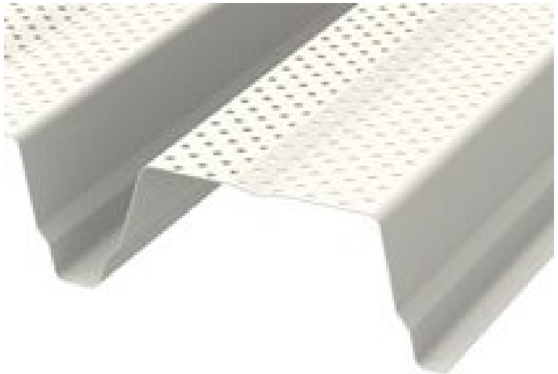
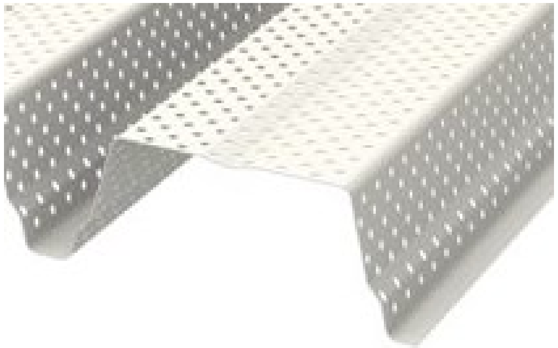
Perforated profiles

1. INTRODUCTION

For architectural reasons and also in order to improve the acoustic performance perforated profiles are increasingly developed and used. Different types, geometries and distribution of micro-perforations exist on the profile webs and on the flanges.





Web perforations **Flange perforations** **Total**

perforations

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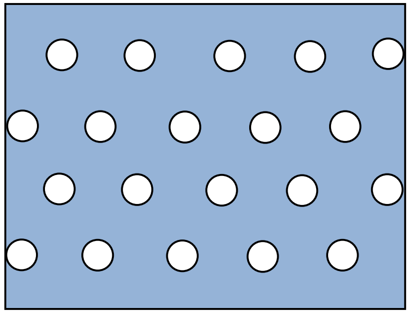
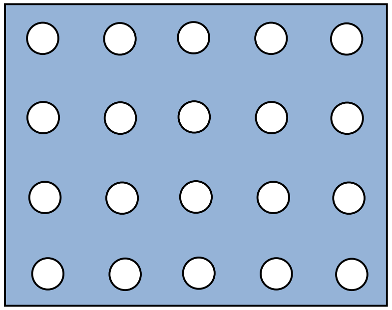
Perforated profiles

1. INTRODUCTION

The perforations are arranged in triangles or in squares





Perforations arranged in triangles

Perforations arranged in squares

The current version EN 1993-1-3 provides the design rules sheeting with triangular equilateral distribution of perforations.

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2. STATE OF THE ART PRE-GRISPE

<u>Section</u> <u>10.4 of EN 1993-1-3:</u> perforated sheeting with the perforations arranged in the shape of equilateral triangles may be designed by calculation, provided that the rules for non-perforated sheeting are modified by introducing the effective thicknesses given below.

- gross section properties may be calculated using 5.1, but replacing t by $t_{a,eff}$ obtained from:

$$t_{a,eff} = 1,18\,t\left(1 - \frac{d}{0,9a}\right) \quad \ldots (10.25)$$

Where: d is the diameter of the perforations;
a is the spacing between the centres of the perforations.

- effective section properties may be calculated using Section 5, but replacing t by $t_{b,eff}$ obtained from:

$$t_{b,eff} = t\sqrt[3]{1,18(1 - d/a)} \quad \ldots (10.26)$$

- the resistance of a single web to local transverse forces may be calculated using 6.1.9, but replacing t by $t_{c,eff}$ obtained from:

$$t_{c,eff} = t\left[1 - (d/a)^2 s_{per}/s_w\right]^{3/2} \quad \ldots (10.27)$$

Where: s_{per} is the slant height of the perforated portion of the web;
s_w is the total slant height of the web.

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2. STATE OF THE ART PRE-GRISPE

Issue identified by the GRISPE project:

- In practice the sheeting with square distribution of perforations is often used. No existing study allows to quantify by calculation the effect of perforations arranged in squares on the steel profile resistance and stiffness.
- The current version EN 1993-1-3 provides the design by calculation rules only with perforations arranged in triangles.
- The only way to design these products is to carry out tests according to EN 1993-1-3 (expensive and time consuming)

There is a real lack of data and knowledge on how to determine resistance and stiffness of steel profile with

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2. STATE OF THE ART PRE-GRISPE

GRISPE objectives and methodology:

The main objectives were to provide technical data and a calculation method for profiles with perforations arranged in squares.

The missing data were determined by testing.

Based on the tests analysis a calculation method was developed and validated

An Amendment was proposed to CEN TC 250/SC3/WG3 EN 1993-1-3

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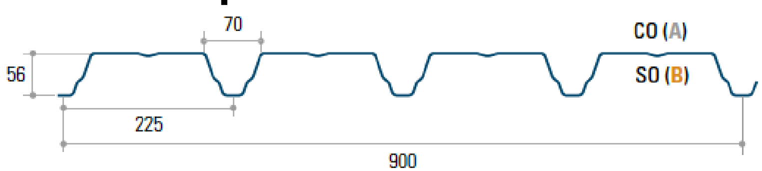
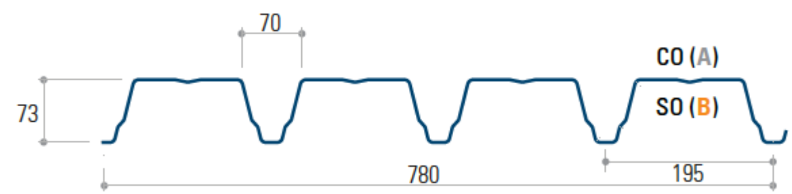
3. TESTING

<u>Aim of the testing</u>:

- to determine local behaviour
- to determine the resistance values of two types of profile without perforations and with flange, web or total perforations arranged ir



<u>Joris Ide PML 56</u>



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- to compare these values for profiles without perforations and with flange, web or total perforations
- arranged in squares

to determine the impact of perforations on the structural behaviour: resistance and stiffness

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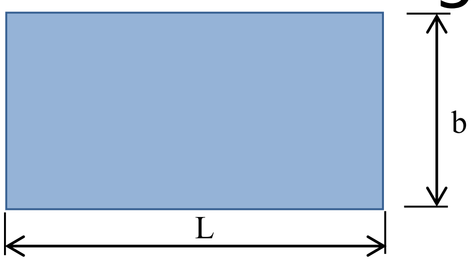
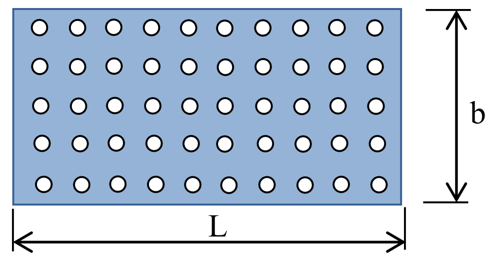
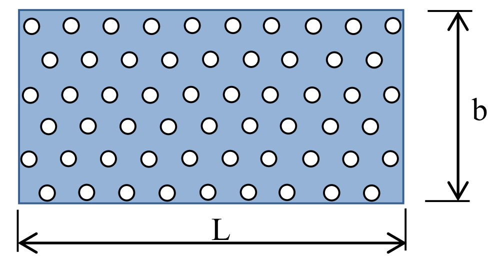
3. TESTING

Local testing performed within the GRISPE project:

Flexion testing :



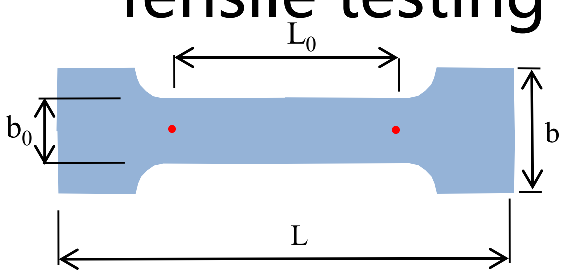


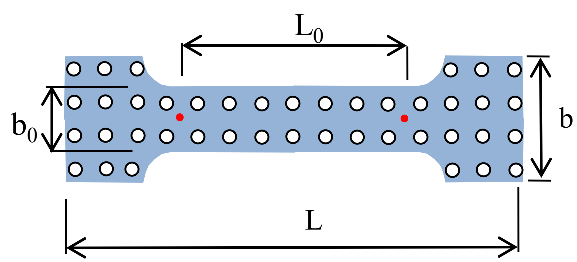


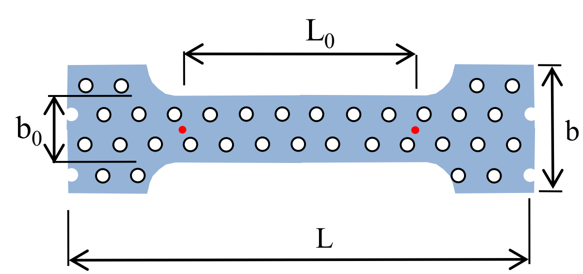
Without perforations With perforations With
perforations

arranged in squares arranged in triangles

Tensile testing :







Without perforations With perforations With
perforations

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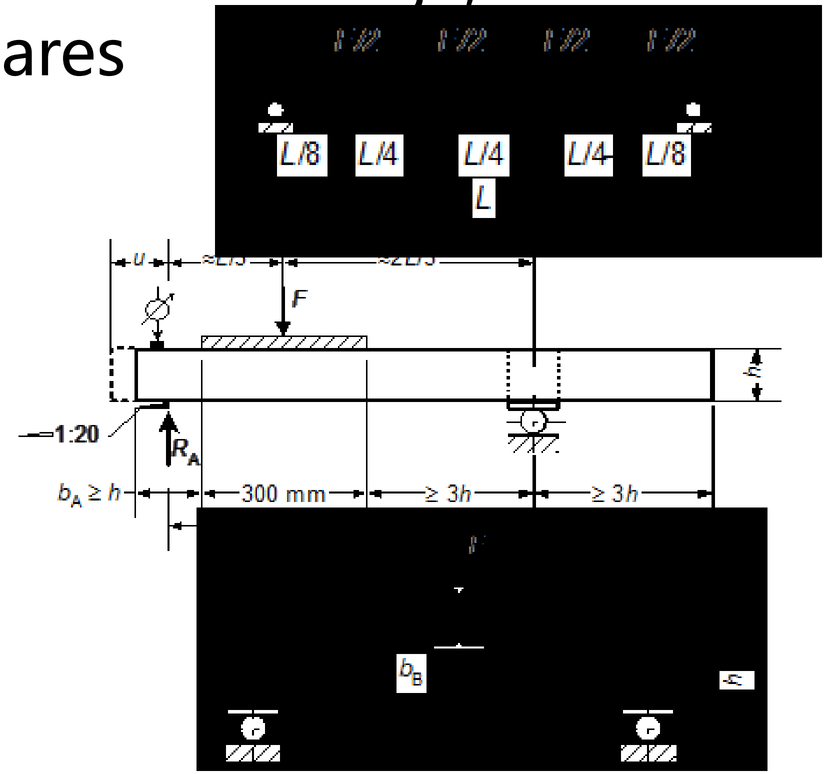
arranged in squares arranged in triangles

3. TESTING

<u>Global testing performed within the GRISPE project</u>:

Tests according to EN 1993-1-3, Annex A, on two types of profile without perforations and with flange, web or total perforations arranged in squares

- Single span test
- End support test
- Internal support test



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3. TESTING

Local behaviour test results:

Analysis of local tests led to an effective thickness (in the meaning of the clause 10.4(2) EN 1993-1-3) for sheeting with perforations arranged in squares as a function of the thickness for sheeting with perforation arranged in triangles:

$$\mathbf{t_{eff}\ (square) = \rho * t_{eff}\ (triangle)\ where\ \rho = 0{,}93}$$

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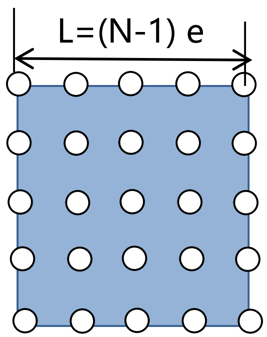
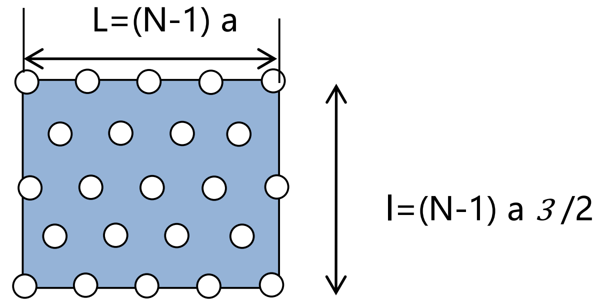
Perforated profiles

3. TESTING

<u>Local behaviour test results:</u>



With perforations arranged in squares



With perforations arranged in triangles

Therefore for the same surface area and the same percentage of perforations

$$a = e\sqrt{\frac{2}{\sqrt{3}}}$$

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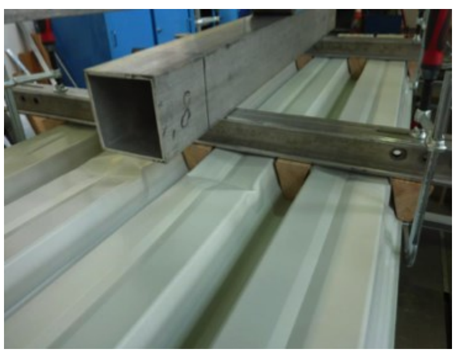
Perforated profiles

3. TESTING

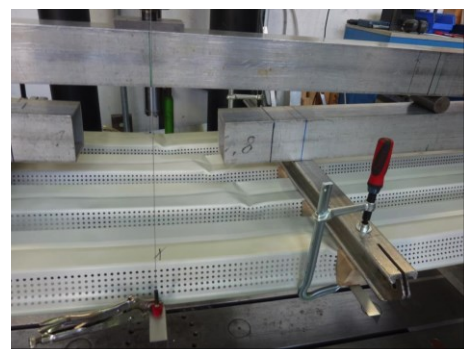
<u>Single span test results</u>:

- Determination of the <u>moment resistance</u> and of the effective flexion <u>stiffness</u> (inertia moment)
- <u>Failure mode</u>: buckling of the upper flanges near the line loads (with and without perforations)

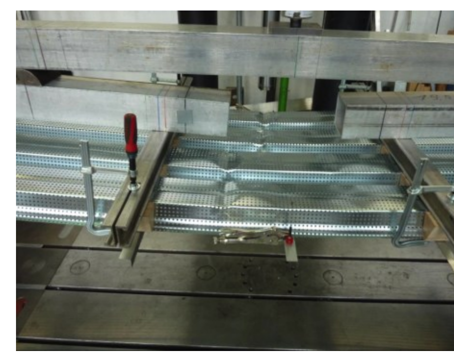


Without perforations

With total perforations



With flange perforations



With web perforations

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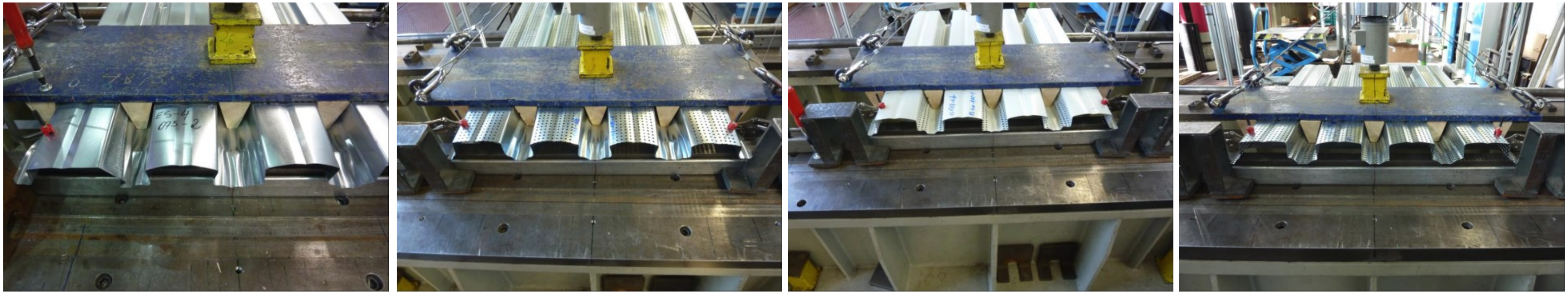
3. TESTING

<u>End support test results</u>:

- Determination of the <u>resistance at end support</u> (web-crippling resistance)
- <u>Failure mode</u>: web-crippling (with and without perforations)



Without perforations

With total perforations

With flange perforations

With web perforations

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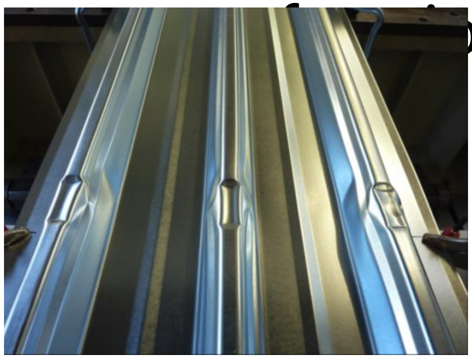
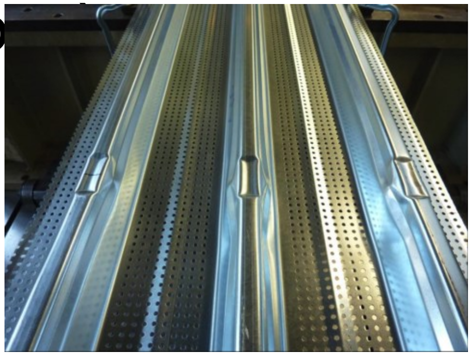
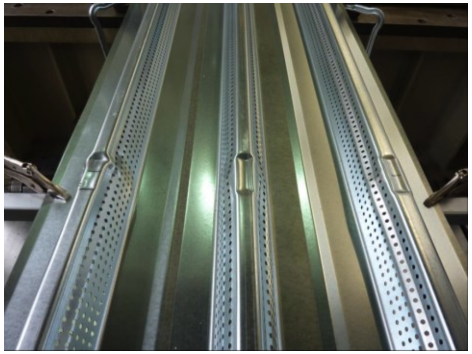
3. TESTING

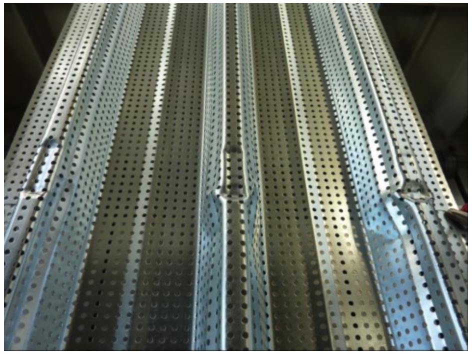
<u>Intermediate support test results</u>:

- Determination of the <u>resistance to combined moment and support reaction</u>
- <u>Failure mode</u>: web crippling due to reaction and buckling due to flexion moment (with and without









Without perforations

With flange perforations

With web perforations

With total perforations

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3. TESTING

<u>Global behaviour test results</u>:

Determination of the effect of perforations on the structural behaviour (resistance and stiffness of the steel profile)

↘	Moment Resistance	Inertia Moment	Reaction Resistance	Moment – Reaction Interaction
Flange perforations	6% - 9%	10%	1% - 4%	0% - 5%
Web perforations	6% - 9%	9% - 11%	24% - 30%	11% - 19%
Total perforations	36% - 37%	33% - 34%	37% - 40%	37% - 40%

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4. DESIGN AND CALCULATION

Moment resistance, web crippling resitance and moment-reaction interaction were also determined by calculation:

- For profiles without perforations with usual EN 1993-1-3 formulas
- For profiles with perforations arranged in squares with EN 1993-1-3 formulas for the perforations arranged in triangles and replacing
  - t_{eff} by 0,93 * t_{eff}
  - a by a = 1,07 * e

Calculated resistances compared to resistances determined by testing

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4. DESIGN AND CALCULATION

<u>Moment resistance:</u>

For perforations in the web or in the flange the difference observed between the calculated moment resistance and the tested one is coherent with the difference observed for the profiles without perforations

Replacing t_{eff} by 0,93 * t_{eff} and a by a = 1,07 * e gives coherent and safe results in relation with the testing results

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4. DESIGN AND CALCULATION

<u>Web crippling resitance:</u>

For the profiles without perforations calculated web crippling resistance at the end support is much lower than the tested one. This confirms the observation noticed in literature that web crippling prediction formula gives the results very different and considerable underestimated compared to the tests results

In coherence with the current clause 10.4(4) only a is replaced by a = 1,07 * e

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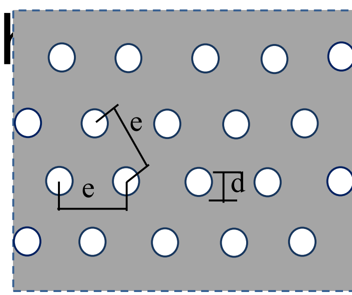
5. PROPOSAL OF AMENDMENTS

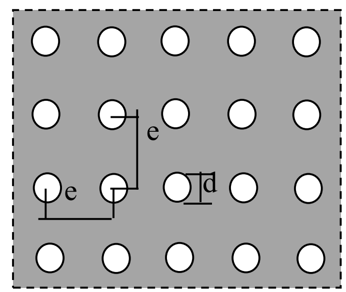
(1) Sheeting with the perforation arranged as follows :

- equilateral triangles pattern
- vertical squares pattern not simultanously in webs and flanges

may be designed by calculation, provided that the rules for non-perforated sheeting are modified by introducing the effective th given



(a)



(b)

NOTE: These calculation rules tend to give rather conservative values. More economical solutions might be obtained from design assisted by testing, see Section 9 (2)

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5. PROPOSAL OF AMENDMENTS

(2) Provided that $0{,}2 \le d/a \le 0{,}9$ gross section properties may be calculated using 5.1, but replacing t by $t_{a,eff}$ obtained from:

- for triangular pattern: $$t_{a,eff} = 1{,}18\, t \left(1 - \frac{d}{0{,}9a}\right) \qquad (10.25a)$$
- for square pattern: $$t_{a,eff} = 1{,}09t \left(1 - \frac{1{,}03d}{a}\right) \qquad (10.25b)$$

where:

d is the diameter of the perforations;

a is the spacing between the centres of the perforations.

Provided that $0{,}2 \le d/a \le 0{,}9$ effective section properties may be calculated using Section 5, but replacing t by $t_{b,eff}$ obtained from:

for triangular pattern: $$t_{b,eff} = t \sqrt[3]{1{,}18\left(1 - \frac{d}{a}\right)} \qquad (10.26a)$$

for square pattern: $$t_{b,eff} = 0{,}98t \sqrt[3]{\left(1 - \frac{0{,}93d}{a}\right)} \qquad (10.26b)$$

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5. PROPOSAL OF AMENDMENTS

(3) The resistance of a single web to local transverse forces may be calculated using 6.1.9, but replacing t by $t_{c,eff}$ obtained from:

- for triangular pattern: $$t_{c,eff} = t\left[1 - \left(\frac{d}{a}\right)^2 \frac{s_{per}}{s_w}\right]^{3/2} \quad (10.27a)$$
- for square pattern: $$t_{c,eff} = t\left[1 - 0,866\left(\frac{d}{a}\right)^2 \frac{s_{per}}{s_w}\right]^{3/2} \quad (10.27b)$$

where:

s_{per} is the slant height of the perforated portion of the web;

s_w is the total slant height of the web.

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6. EXCEL SHEETS

Four Excel sheets were developed to provide a reliable design procedure in order to encourage and facilitate the use of steel decks with perforations arranged in squares.

The overall aim was to achieve simple, clear, easy to understand and easy to use excel sheets. The excel sheets were validated by the comparison of the calculation results with all the tests which have been carried out. Moreover the calculation methods have been made available to a number of industry users to verify their fitness for purpose.

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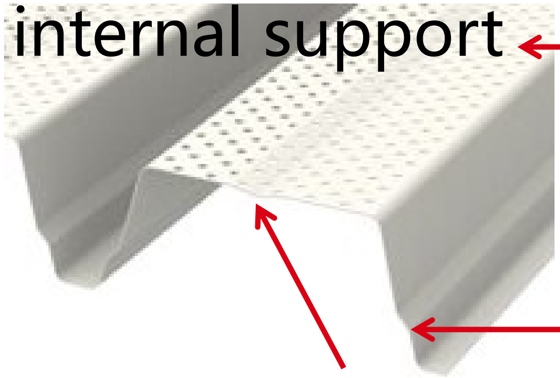
6. EXCEL SHEETS

- Profile with one flange stiffener and one web stiffener, with perforation arranged in squares, in the upper flange
  1) calculation of span moment resistance and end support reaction
  2) calculation of moment-reaction interaction at internal support



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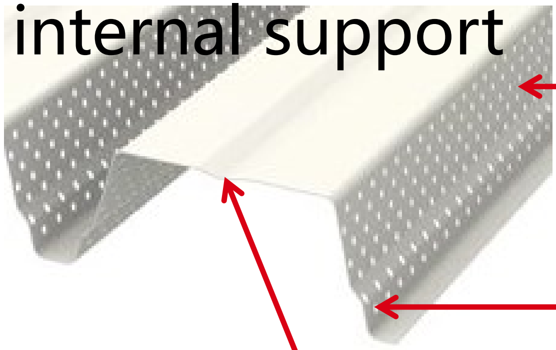
6. EXCEL SHEETS

- Profile with one flange stiffener and one web stiffener, with perforations arranged in squares, in the web
  1) calculation of span moment resistance and end support reaction
  2) calculation of moment-reaction interaction at internal support



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7. CONCLUSION

- The design by calculation methods of perforated profiles presented here, were checked and validated by an extensive test programme performed within the GRISPE project.
- Four Excel sheets including these methods were developed :
  - for two types of profile
  - for calculation of moment resistance, end support reaction and moment-reaction interaction at internal support
- This design by calculation method was proposed for amendment on EN 1993-1-3 within CEN/TC250 Subcommittee 3 (SC3) “Steel Structures”.

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for your attention

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