GRISPE PLUS

VALORISATION OF KNOWLEDGE FOR SPECIFIC PROFILED STEEL SHEETS

STEEL DECKS WITH EMBOSSMENTS / INDENTATIONS

Anna PALISSON

Sources

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

Steel decks with embossments / indentations

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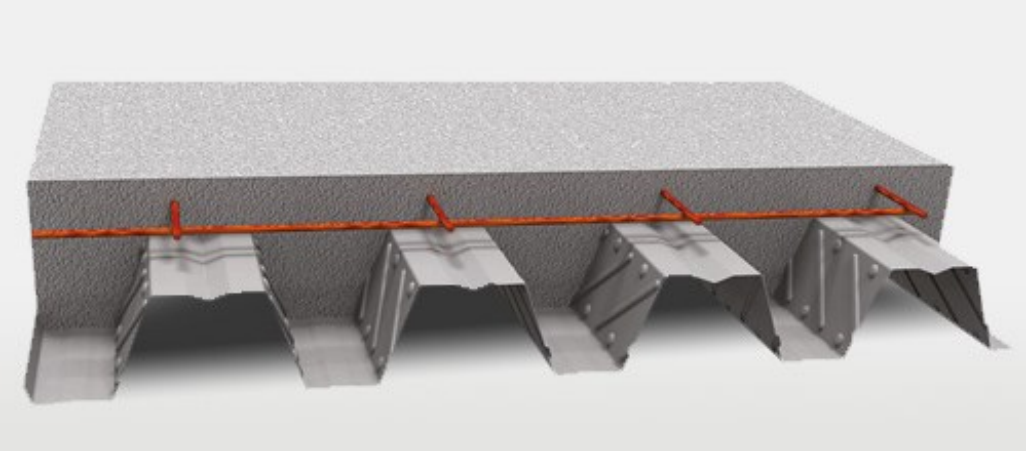
Steel decks with embossments / indentations

1. INTRODUCTION



Bacacier PCB 80 steel deck

Due to its many construction advantages steel decking is frequently used in steel-framed construction for both roofs and floors, commercial and industrial refurbishments and for industrial buildings, , as well for new constructions as for refurbishments.

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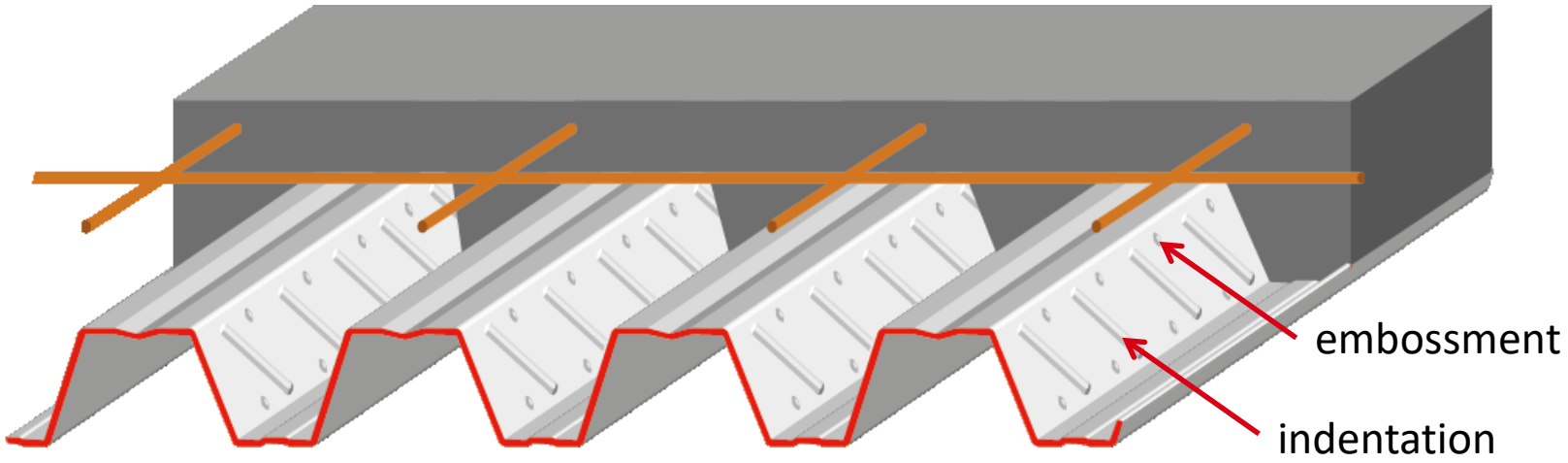
Steel decks with embossments / indentations

1. INTRODUCTION

In order to increase the shear connection between the steel and the concrete in the composite slabs, steel decks are reinforced with connectors such as embossments or indentations on the webs.



Bacacier PCB 80 steel deck

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Steel decks with embossments / indentations

2. STATE OF THE ART PRE-GRISPE

Composite stage (steel + concrete) :

- The behavior of composite decks with embossments / indentations has been described by numerous studies.
- Steel sheeting with embossments / indentations are within the scope of the European standard EN 1994-1-1 for the design of composite structures (steel and concrete).

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Steel decks with embossments / indentations

2. STATE OF THE ART PRE-GRISPE

Construction stage:

- The sheeting used as shuttering has to support the fresh concrete weight and the construction loads. No existing study allows to quantify by calculation the effect of embossments / indentations on the steel profile resistance and stiffness.
- The European Standard EN 1993-1-3 dealing with design rules for cold-formed members and sheeting does not cover profiled sheeting with embossments /
- indentations.
  The only option for manufacturers to design these products is to carry out tests according to EN 1993-1-3, moreover these tests are expensive and time consuming

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Steel decks with embossments / indentations

2. STATE OF THE ART PRE-GRISPE

Issue identified by the GRISPE project:

EN 1994-1-1 specifies that steel sheeting should be designed in accordance with EN 1993-1-3, but EN 1993-1-3 does not provide any information about the design and verification of profiles with indentations / embossments.

There is a real lack of data and knowledge about the impact of embossments / indentations on steel profile resistance and stiffness.

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Steel decks with embossments / indentations

2. STATE OF THE ART PRE-GRISPE

GRISPE objectives and methodology:

The main objectives were to provide technical data and a calculation method for steel decks with embossments / indentations. Despite their growing importance in the construction industry in Europe, no calculation method is included in the current version of Eurocode EN 1993-1-3.

The missing data were determined by testing.

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

Two Amendments were proposed to CEN TC 250/SC3/WG3 EN 1993-1-3

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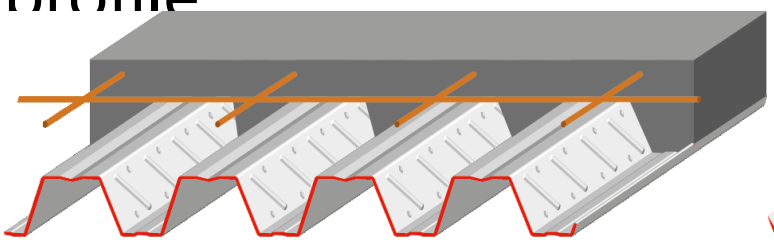
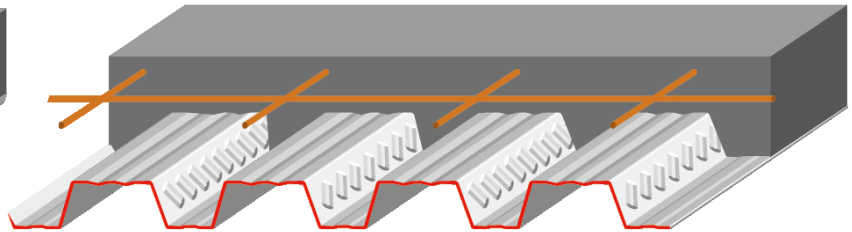
Steel decks with embossments / indentations

3. TESTING

Aim of the testing:

- to determine local behaviour
- to determine the resistance values of two types of profile





- Bacacier PCB 80 — Bacacier PCB 60
- to compare these values for profiles with and without embossments / indentations.
- to determine the impact of embossments / indentations on the structural behaviour: resistance and stiffness

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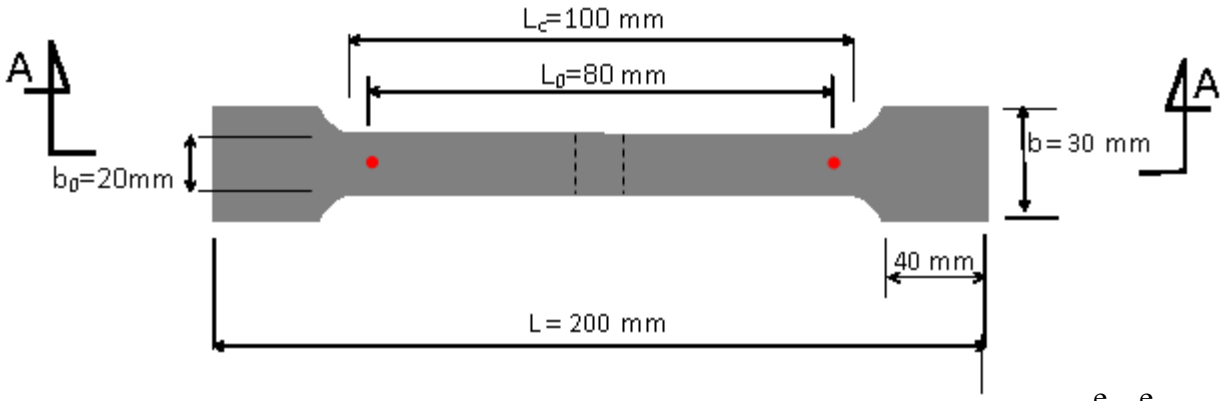
Steel decks with embossments / indentations

3. TESTING

Tests performed within the GRISPE project:

Local behaviour of profiles with embossments / indentations tested on samples:



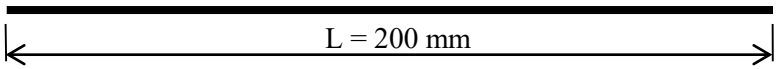
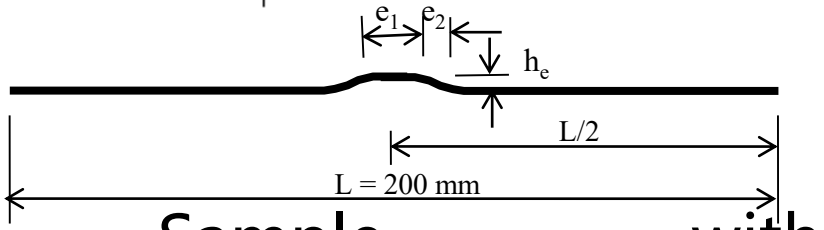


Plate sample



Sample with indentation

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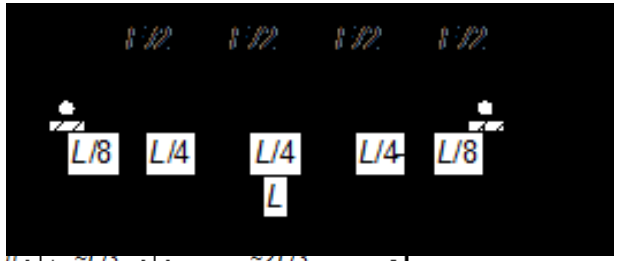
Steel decks with embossments / indentations

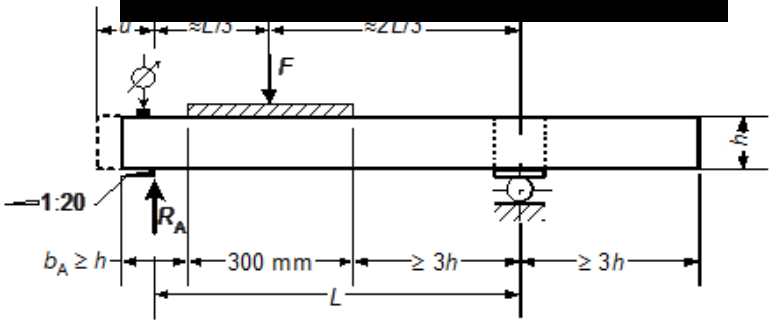
3. TESTING

<u>The tests performed within the GRISPE project</u>:
Global behaviour tested according to EN 1993-1-3, Annex A:

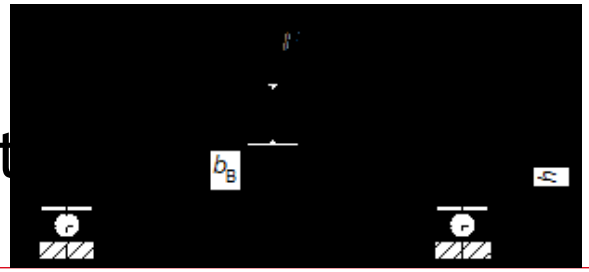
- Single span



- End suppor



- Internal support



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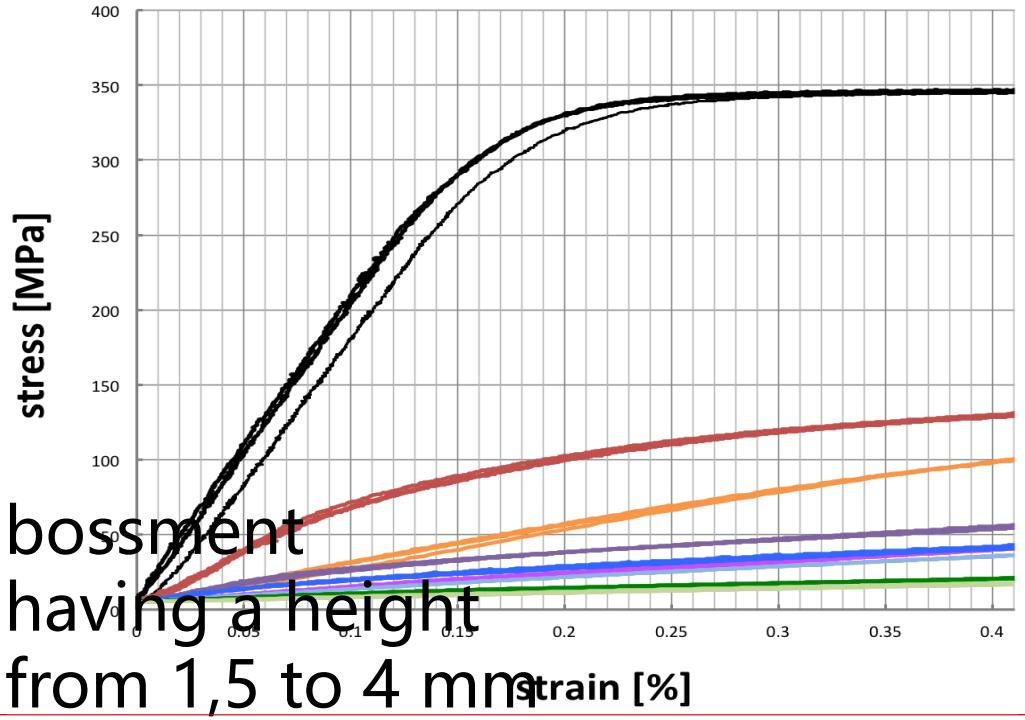
Steel decks with embossments / indentations

3. TESTING

Local behaviour test results: The stress decreases in accordance with embossments. The higher the embossment is the more the stress decreases.

Stress strain curves



Without any embossment

With embossment having a height from 1,5 to 4 mm

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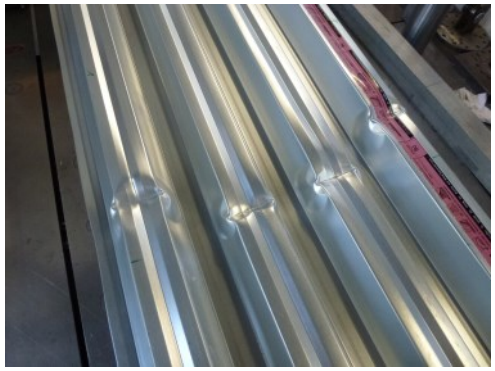
Steel decks with embossments / indentations

3. TESTING

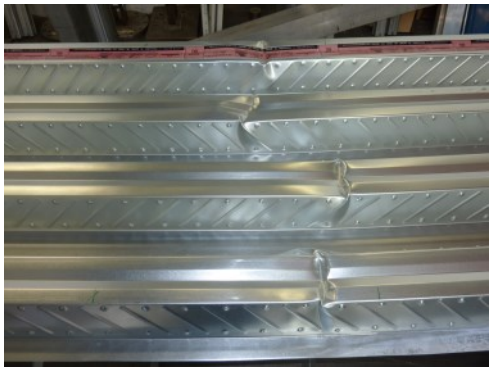
Single span test results:

- Determination of the moment resistance and of the effective flexion stiffness (inertia moment)
- Failure mode: buckling of the upper flange near the line loads (with and without embossments / indentations)

Test set-up



Without embossments/ indentations



With embossments / indentations

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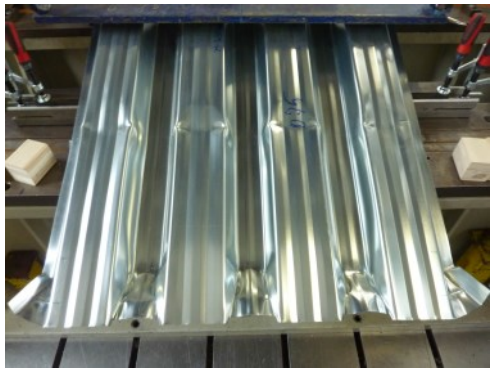
Steel decks with embossments / indentations

3. TESTING

End support test results:

- Determination of the resistance at end support (web-crippling resistance)
- Failure mode: web-crippling (with and without embossments / indentations)

Test set-up



Without embossments/ indentations

With embossments / indentations

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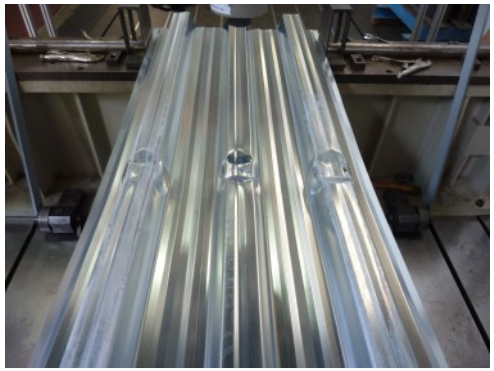
Steel decks with embossments / indentations

3. TESTING

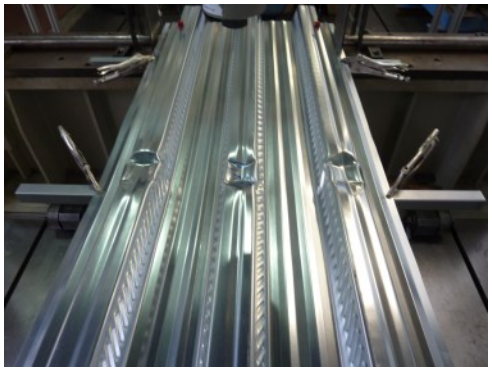
Intermediate support test results:

- Determination of the resistance to combined moment and support reaction
- Failure mode: web-crippling (with and without embossments / indentations)

Test set-up embossments / indentations



Without embossments/ indentations



With indentations

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Steel decks with embossments / indentations

3. TESTING

Global behaviour test results:

Determination of the effect of embossments and indentations on the structural behaviour (resistance and stiffness of the steel decks)

Moment Resistance	**Inertia Moment**	**Reaction Resistance**	**Moment – Reaction Interaction**	
			smaller span (0,4-0,5m)	bigger span (1,5-1,7m)
↘	↘	↗	≥ (governed by Reaction Resistance)	≤ (governed by Moment Resistance)

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Steel decks with embossments / indentations

4. DESIGN AND CALCULATION

Local behaviour tested on coupons:

A detailed analysis allowed to determine a ratio between the yield stress of the sample without embossment and the yield stress of the sample with embossment.

The influence of an embossment on the resistance is determined by modeling the plate element with an embossment as a plate element with reduced thickness instead of embossment: $\mathbf{t_{red} = \rho * t}$

where ρ depends on the height of the embossment h_e and on the thickness t

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Steel decks with embossments / indentations

4. DESIGN AND CALCULATION

Local behaviour tested on samples:

t = 0,75 mm	
h_e (mm)	$\rho_p = K_{pe}/K_p$
1,5	0,200
2	0,150
2,5	0,080
2,75	0,060
3	0,053
3,5	0,041
4	0,029

t = 1 mm	
h_e (mm)	$\rho_p = K_{pe}/K_p$
1,5	0,300
2	0,181
2,5	0,084
2,75	0,067
3	0,062
3,5	0,052
4	0,042

Ratio ρ depending on the embossment height for t = 0,75 mm and for t = 1 mm

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Steel decks with embossments / indentations

4. DESIGN AND CALCULATION

Global behaviour:

Moment resistance, web crippling resistance and moment-reaction interaction were determined:

- For profiles without embossments / indentations with usual EN 1993-1-3 formulas
- For profiles with embossments / indentations considering the embossments / indentations as plate elements with a reduced thickness $\mathbf{t_{red}} = \rho * \mathbf{t}$ where $\rho = \mathbf{A*h + B}$, h is height of the embossments / indentations , A and B are coefficients given in next table:

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Steel decks with embossments / indentations

4. DESIGN AND CALCULATION

Global behaviour:

Type of local deformation	t (mm)	h (mm)	A	B
Indentation	0.71	0 - 1.5	-0.533	1.000
		1.5 - 2.75	-0.112	0.368
		2.75 - 4.0	-0.025	0.128
	0.96	0 - 1.5	-0.467	1.000
		1.5 - 2.75	-0.186	0.580
		2.75 - 4.0	-0.020	0.122
	1.21	0 - 1.5	-0.401	1.000
		1.5 - 2.75	-0.260	0.792
		2.75 - 4.0	-0.015	0.116

Type of local deformation	t (mm)	h (mm)	A	B
Embossment	0.71	0 - 1.5	-0.267	1.000
		1.5 - 2.75	-0.056	0.684
		2.75 - 4.0	-0.013	0.564
	0.96	0 - 1.5	-0.234	1.000
		1.5 - 2.75	-0.093	0.790
		2.75 - 4.0	-0.010	0.561
	1.21	0 - 1.5	-0.201	1.000
		1.5 - 2.75	-0.130	0.896
		2.75 - 4.0	-0.008	0.558

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Steel decks with embossments / indentations

4. DESIGN AND CALCULATION

Moment resistance:

For the profiles with embossments / indentations, the difference observed between the calculated moment resistance and the tested one is coherent with the difference observed for the profiles without embossments / indentations

Considering the embossments / indentations as flat elements with a reduced thickness $\mathbf{t_{red}} = \rho * \mathbf{t}$ where $\rho = \mathbf{A*h + B}$, h is height of the embossments / indentations , A and B are coefficients defined as before, gives coherent and safe results in relation with the testing results

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Steel decks with embossments / indentations

4. DESIGN AND CALCULATION

Web crippling resitance:

- web crippling resistance at the end support of the profiles with embossments / indentations is slightly higher that this of the profiles without embossments / indentations,
  test values are much bigger in both cases than the calculated ones

As a safe simplification, the web crippling resistance may be determined without considering embossments / indentations

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Steel decks with embossments / indentations

5. PROPOSAL OF AMENDMENTS

A - Effective section of sheeting with indentation and/or embossment: Proposed change

(1) The effective width of plane wall with indentations (Fig. 5.15a) or embossments (Fig. 5.15b) should be first calculated according to 5.5.1(2)

(2) In the second step, the indentation or embossment should be taken into account considering the embossments / indentations (Fig. 5.15a / 5.15b) as plate elements with reduced thickness $t_{red} = \rho * t$ where:

- $\rho = A*h + B$
- h is height of the indentation / embossment in mm (see Figures 5.15a and 5.15b)
- A and B are coefficients given in table 5.3.

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Steel decks with embossments / indentations

5. PROPOSAL OF AMENDMENTS

A - Effective section of sheeting with indentation and/or embossment: Proposed change

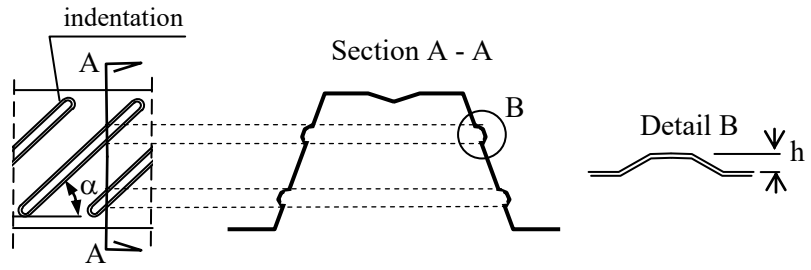

Figure 5.15a Exemple of sheeting with indentations

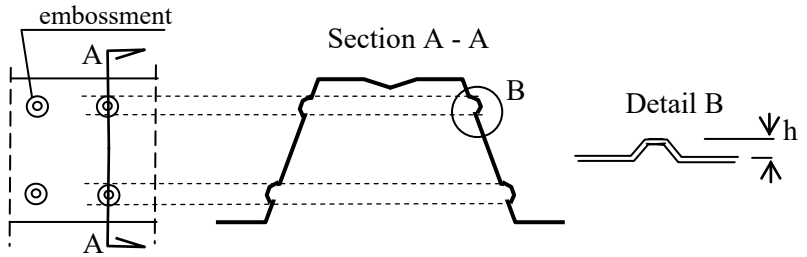

Figure 5.15b Exemple of sheeting with embossment

Table 5.3: Values of coefficients A and B (equation (5.43)

Type of local deformation	t (mm)	h (mm)	A	B
Indentation	0.71	0 - 1.5	-0.533	1.000
		1.5 - 2.75	-0.112	0.368
		2.75 - 4.0	-0.025	0.128
	0.96	0 - 1.5	-0.467	1.000
		1.5 - 2.75	-0.186	0.580
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Steel decks with embossments / indentations

5. PROPOSAL OF AMENDMENTS

A - Effective section of sheeting with indentation and/or embossment: Proposed change

(3) The cross section for calculation of the effective section should be positioned so as to cause the most unfavorable effect

(4) Range of validity

- 0,71 mm $\leq$ t $\leq$ 1,21 mm
- $h \leq$ 4,0 mm

  30° $\leq$ α $\leq$ 60°

(5) For intermediate thicknesses the reduction factor ρ may be deteminated by means of linear interpolation between the neighboring t values given in the Table 5.3. For t > 1,21 mm the values given for t = 1,21 mm may be conservatively adopted.

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Steel decks with embossments / indentations

5. PROPOSAL OF AMENDMENTS

<u>2) Resistance of sheeting with indentations or embossment to combined bending moment and local load or support reaction :</u> Proposed change

Add a new clause:

(2) In case of sheeting with indentations or embossments, the equations (6.28a), (6.28b) and (6.28c) from the AMD-1-3-2013-14 may be used with:

- $M_{c,Rd}$ = resistance moment determined considering the identations and/or embossments according to the
- Proposal 1

  $R_{w,Rd}$ = local transverse resistance determined without considering the identations and/or embossments

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Steel decks with embossments / indentations

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 embossments / indentations.

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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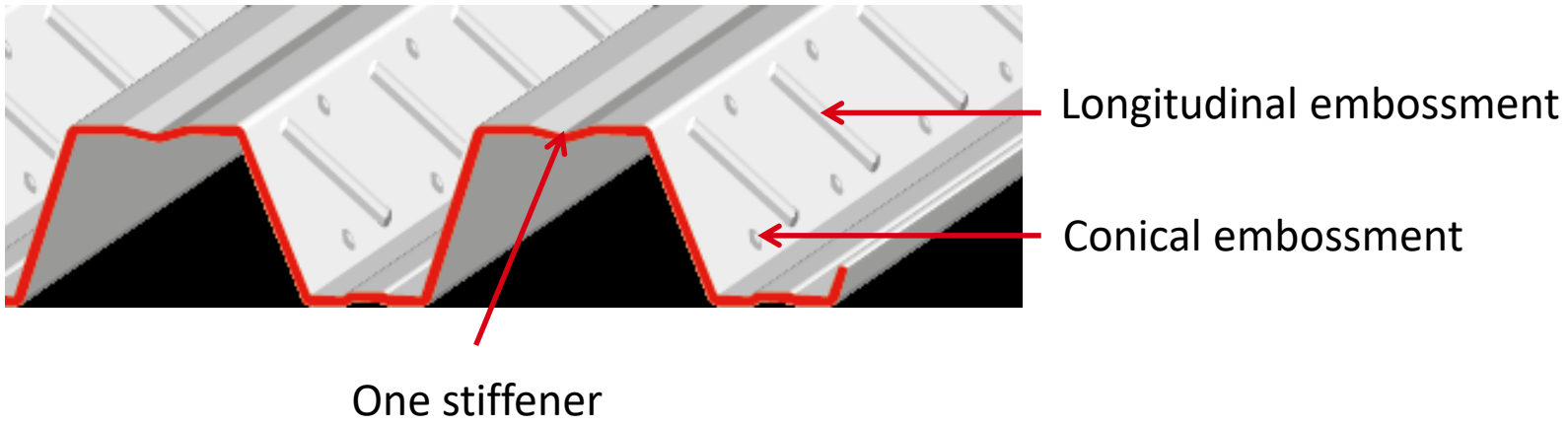
Steel decks with embossments / indentations

6. EXCEL SHEETS

- Profile with one stiffener in the upper flange, with longitudinal and conical embossments
  1) calculation of span moment resistance and end support reaction
  2) calculation of moment-reaction interaction at internal support



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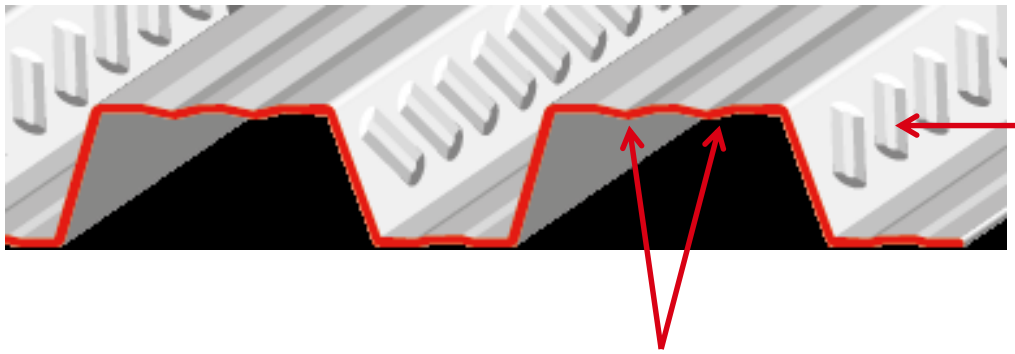
Steel decks with embossments / indentations

6. EXCEL SHEETS

- Profile with two stiffeners in the upper flange, with longitudinal embossments
  1) calculation of span moment resistance and end support reaction
  2) calculation of moment-reaction interaction at internal support



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Steel decks with embossments / indentations

7. CONCLUSION

- The design by calculation methods of steel decks with embossments / indentations 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

These design by calculation methods were presented for proposal of Amendments on EN 1993-1-3 within CEN/TC250 Subcommittee 3 (SC3) "Steel Structures".

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Thank you for your attention

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