GRISPE

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

Working Package 1

WP1 Test analysis and interpretation

30th June 2015

Deliverable D 1.4

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

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Deliverable	
D 1.4 WP1 Test analysis and interpretation	***Due date : 30.06.2015*** ***Completion date: 30.06.2015***

1. INTRODUCTION

1.1. Aim of the tests analysis and interpretation

At the construction stage the sheeting used as shuttering has to support the unhardened concrete weight and the construction loads, and in this case the effect of the embossments and indentations may be not favorable. Unfortunately the EN 1993-1-3 dealing with design rules for cold-formed members and sheeting doesn't cover profiles with embossments, indentations or outwards stiffeners. Moreover the existing studies and researches on this type of profile don't allow to quantify precisely by calculation the effect of embossment and indentations on the steel deck resistance and stiffness and to predict the bending resistance of sheeting with outwards stiffener in the upper flange. A study performed by P. Luure and M. Crisinel [1] shows an influence of about 10% on the resistance and on the stiffness. J. M. Davies [2] found in his finite element analysis a decrease of 8 to 10% of the bending strength for dimples in top flange, for dimples in the webs the decrease of bending strength was less important, about 3%. Unfortunately both studies don't take into account the effect of combined action of support reaction and negative moment whereas the interactive moment-reaction resistance would be different then the resistance of pure bending M_R or contact pure pressure F_R, as it could be shown for corrugated sheets by A. Biegus [3].

Therefore the aim of the tests analysis and interpretation is:

- to determine the resistance values of different types of sheeting
- to compare these values for sheeting without and with embossments/indentations
- to determine the effect of embossment and indentations on the structural behaviour: resistance and stiffness of the steel decks;

1.2. General

A huge test program including 152 tests was performed on steel trapezoidal sheeting.
Two different profiles PCB 60 and PCB 80 from BACACIER with different shapes of embossments/indentations (decking 1 and decking 2) were tested. The same profiles were tested with and without embossments/indentations, with two different thicknesses of the sheets.

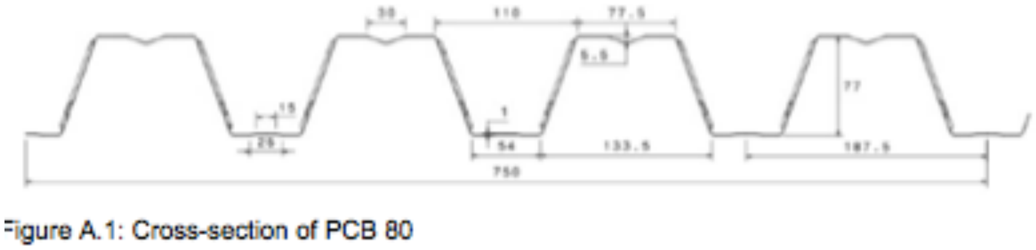


Fig. 1.2.1: PCB 80 from BACACIER SAS

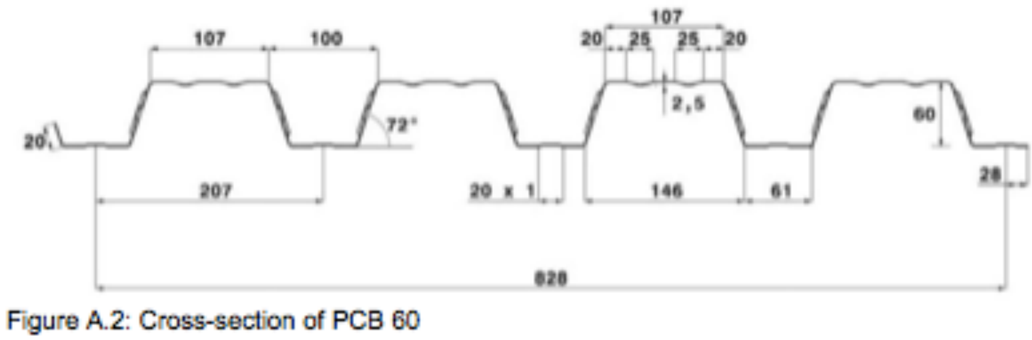


Fig. 1.2.2: PCB 60 from BACACIER SAS

The Comflor® 80 sheeting from TataSteel with outwards stiffener in the upper flange was tested, with two different thicknesses.

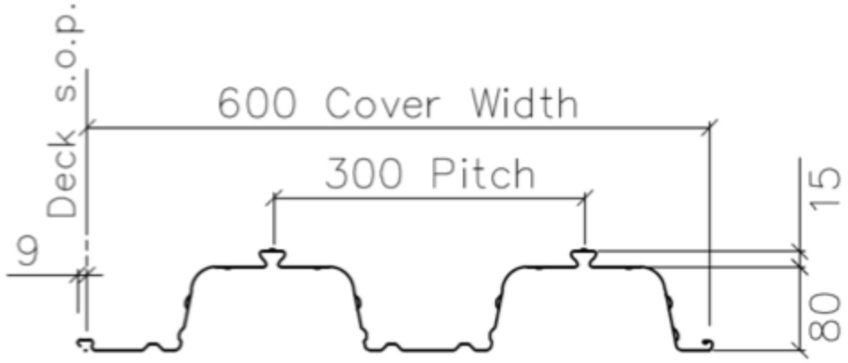


Fig. 1.2.3: ComFlor® 80 from TataSteel

The global behaviour of profiles were tested according to EN 1993-1-3, Annex A:

- single span tests for PCB 60, PCB 80 and Comflor® 80 ,
- internal support tests for PCB 60 PCB 80
- end support tests for PCB 60 and PCB 80.

The local behaviour of sheets with indentations/embossments was tested on coupon tests.

1.3 Adjustment of test results

Test results are adjusted to allow for variations between the actual observed properties of the test specimen and their nominal values according to section A.6.2 of EN 1993-1-3

The adjusted value $R_{adj,i}$ of the test result for test i is determined from the actual observed values, $R_{obs,i}$ using :

$$R_{adj,i} = R_{obs,i} / \mu_R$$

in which μ_R is the resistance adjustment coefficient given by:

$$\mu_R = \left(\frac{f_{yb,obs}}{f_{yb}}\right)^{\alpha} \left(\frac{t_{obs,cor}}{t_{cor}}\right)^{\beta}$$

For the resistance:

- The exponent α is defined as follows :

- if $f_{yb,obs} \leq f_{yb}$: $\alpha = 0$

- if $f_{yb,obs} > f_{yb}$:

generaly : $\alpha = 1$

For profiled sheets or liner trays in which compression elements have such large b_p/t ratios that local buckling is clearly the failure mode: $\alpha = 0{,}5$

- The exponent β is defined as follows :

- if $t_{obs,cor} \leq t_{cor}$: $\beta = 1$
- if $t_{obs,cor} > t_{cor}$:

  for tests on profiled sheets or liner trays: $\beta = 2$

For inertia moment according to Corrigendum CEN/TC/250/SC3, N° N1645E of 9th October 2008

$\alpha = 0$

$\beta = 1$

2 RESISTANCE VALUES

2.1 Adjustment of test results

PCB 80:

Single span and end support tests

Thickness 0.75 mm

P.p. kN/m^2								μ_R		Correction	
	B (m)	f_{yb}	$f_{y,obs}$	t_{cor}	$t_{obs,cor}$	α	β	Resist	Inertie	Resist	Inertie
0,0939	0,75	320	362,80	0,71	0,68	0,5	1	1,026	0,964	0,770	0,723

Thickness 1.00 mm

P.p. kN/m^2								μ_R		Correction	
	B (m)	f_{yb}	$f_{y,obs}$	t_{cor}	$t_{obs,cor}$	α	β	Resist	Inertie	Resist	Inertie
0,1253	0,75	320	369,80	0,96	0,961	0,5	2	1,076	1,001	0,807	0,750

Intermediate support tests

Thickness 0.75 mm

P.p. kN/m^2	B (m)	f_{yb}	$f_{y,obs}$	t_{cor}	$t_{obs,cor}$	α	β	μ_R	Correct.
0,0939	0,5625	320	362,80	0,71	0,68	0,5	1	1,026	0,577

Thickness 1.00 mm

P.p. kN/m^2	B (m)	f_{yb}	$f_{y,obs}$	t_{cor}	$t_{obs,cor}$	α	β	μ_R	Correct.
0,1253	0,5625	320	369,80	0,96	0,961	0,5	2	1,076	0,605

PCB 60:

Single span and end support tests

Thickness 0.75 mm

P.p. kN/m^2								μ_R		Correction	
	B (m)	f_{yb}	$f_{y,obs}$	t_{cor}	$t_{obs,cor}$	α	β	Resist	Inertie	Resist	Inertie
0,0867	0,8	320	340,80	0,71	0,698	0,5	1	1,014	0,983	0,811	0,786

Thickness 1.00 mm

P.p. kN/m^2								μ_R		Correction	
	B (m)	f_{yb}	$f_{y,obs}$	t_{cor}	$t_{obs,cor}$	α	β	Resist	Inertie	Resist	Inertie
0,1157	0,8	320	364,00	0,96	0,932	0,5	1	1,035	0,970	0,828	0,776

Intermediate support tests

Thickness 0.75 mm

P.p. kN/m^2	B (m)	f_{yb}	$f_{y,obs}$	t_{cor}	$t_{obs,cor}$	α	β	μ_R	Correct.
0,0867	0,621	320	340,80	0,71	0,698	0,5	1	1,014	0,630

Thickness 1.00 mm

P.p. kN/m^2	B (m)	f_{yb}	$f_{y,obs}$	t_{cor}	$t_{obs,cor}$	α	β	μ_R	Correct.
0,1157	0,621	320	364,00	0,96	0,932	0,5	1	1,035	0,643

COMFLOR 80®:

Thickness 0.90 mm

P.p.								μ_R		Correction	
kN/m^2	B (m)	f_{yb}	$f_{y,obs}$	t_{cor}	$t_{obs,cor}$	α	β	Resist	Inertie	Resist	Inertie
0,11	0,6	450	470,50	0,86	0,875	0,5	2	1,058	1,017	0,635	0,610

Thickness 1.20 mm

P.p.								μ_R		Correction	
kN/m^2	B (m)	f_{yb}	$f_{y,obs}$	t_{cor}	$t_{obs,cor}$	α	β	Resist	Inertie	Resist	Inertie
0,15	0,6	450	467,50	1,16	1,164	0,5	2	1,026	1,003	0,616	0,602

2.2 Single span tests

Tests set-up:

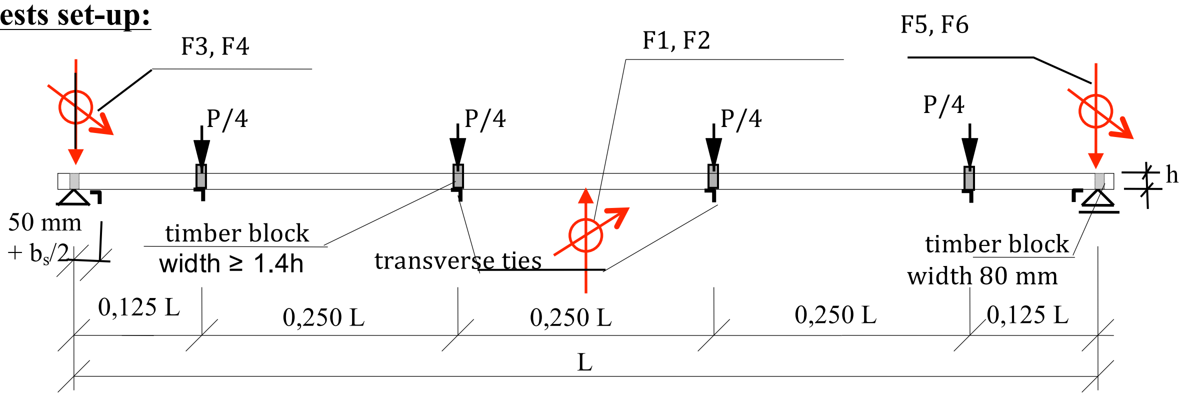


Fig. 2.2.1 – Test set-up for single span tests

The failure mode observed was the same for profiles without and with embossments and indentations. In all tests failure occurred by buckling of the upper flange near the load applying traverse.

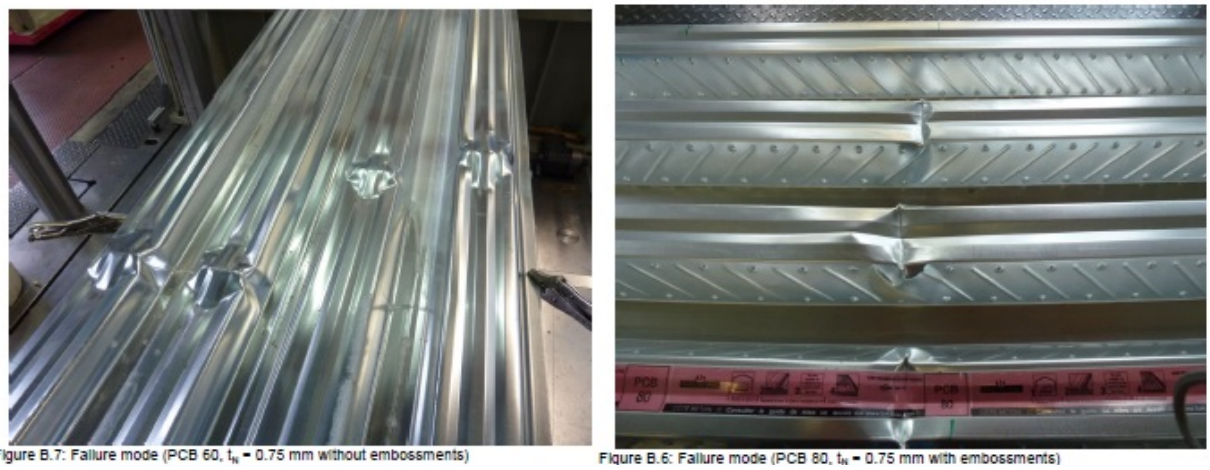


Figure B.7: Failure mode (PCB 60, t_N = 0.75 mm without embossments)

Figure B.6: Failure mode (PCB 80, t_N = 0.75 mm with embossments)

Fig. 2.2.2 – Failure mode (PCB 60, 0,75mm without and with embossments)

Resistance Moment and Inertia Moment for 1m width of profile:

PCB 80:

PCB 80	without embossements	with embossements	
t_{nom}	M_R	M_R	Embossment
mm	kN*m/m	kN*m/m	influence
0,75	8,77	8,47	-3,5%
1,00	12,65	12,14	-4,1%

PCB 80	without embossements	with embossements	
t_{nom}	I_{eff}	I_{eff}	Embossment
mm	mm4/m	mm4/m	influence
0,75	1031600	921125	-10,7%
1,00	1277505	1200552	-6,0%

PCB 60:

PCB 60	without embossements	with embossements	
t_{nom}	M_R	M_R	Embossment
mm	kN*m/m	kN*m/m	influence
0,75	4,97	4,48	-9,7%
1,00	7,15	6,83	-4,4%

PCB 60	without embossements	with embossements	
t_{nom}	I_{eff}	I_{eff}	Embossment
mm	mm4/m	mm4/m	influence
0,75	526483	494139	-6,1%
1,00	680177	670761	-1,4%

COMFLOR 80:

COMFLOR 80	
t_{nom} mm	M_R kN*m/m
0,90	12,76
1,20	21,18

COMFLOR 80	
t_{nom} mm	I_{eff} mm4/m
0,90	1420899
1,20	1936271

The embossments decrease resistance moment from 3,5% up to 9,7%, and decrease inertia moment from 1,4% up to 10,7%. It is consistent with the study performed by P. Luure and M. Crisinel [1] which showed a decrease of about 10% on the resistance and with the study performed by J. M. Davies [2] who found in his finite element analysis a decrease of 3 to 10% of the bending strength.

2.3 End support tests

Test set-up:

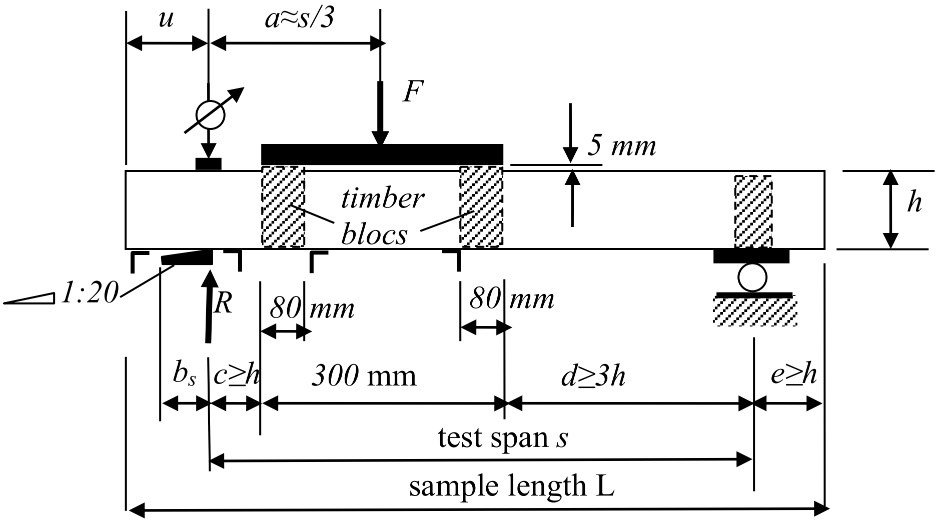


Fig. 2.3.1 – Test set-up for end support test

Web-crippling occurred in all profiles without and with embossments and indentations.

Figure D.13: Web-crippling (PCB 60 t_N = 1.00 mm without embossments)

Figure D.16: Web-crippling (PCB 60 t_N = 0.75 mm with embossments)

Fig. 2.3.2 – Web-crippling (PCB 60, 1 mm without and with embossments)

Web crippling resistance for 1m of profile:

PCB 80:

PCB 80	without embossements	with embossements	
t_{nom} mm	R_{Rd} kN/m	R_{Rd} kN/m	Embossment influence
0,75	15,64	16,49	5,5%
1,00	27,73	29,23	5,4%

PCB 60:

PCB 60	without embossements	with embossements	
t_{nom} mm	R_{Rd} kN/m	R_{Rd} kN/m	Embossment influence
0,75	22,11	26,58	20,3%
1,00	35,77	38,21	6,8%

We can observe that the embossments increase web crippling resistance from 5,5% up to 20,3%. P. Luure and M. Crisinel [1] found an increase of about 10%, which is consistent with our values.

2.4 Internal support tests

Test set-up:

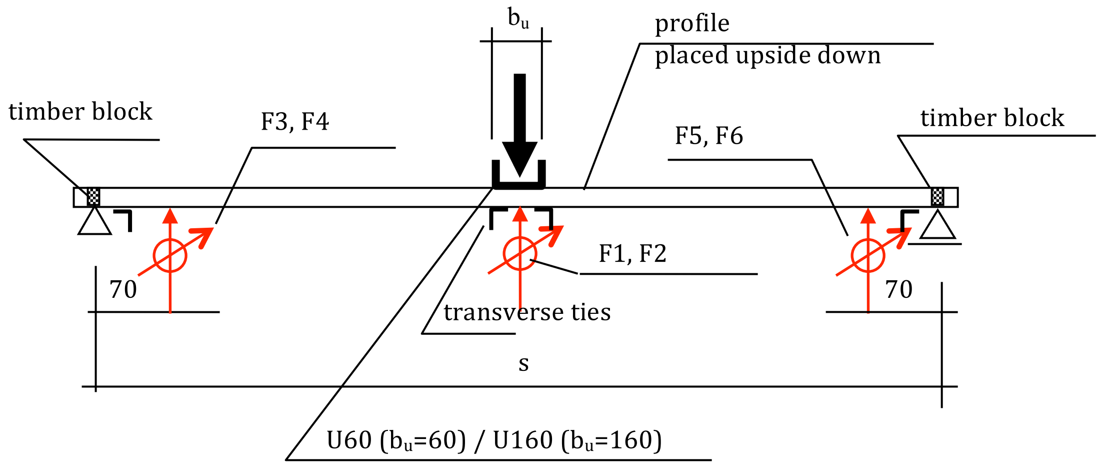


Fig. 2.4.1 – Test set-up for internal support tests

The rotation is obtained in accordance with EN 1993-1-3 using:

$$\theta = \frac{2(\delta_{pl} - \delta_{lin})}{0{,}5s - e}$$

where: δ_{pl} = average deflection measured at mid-span by sensors 1 and 2
δ_{lin} = deflection that would be obtained with a linear behaviour

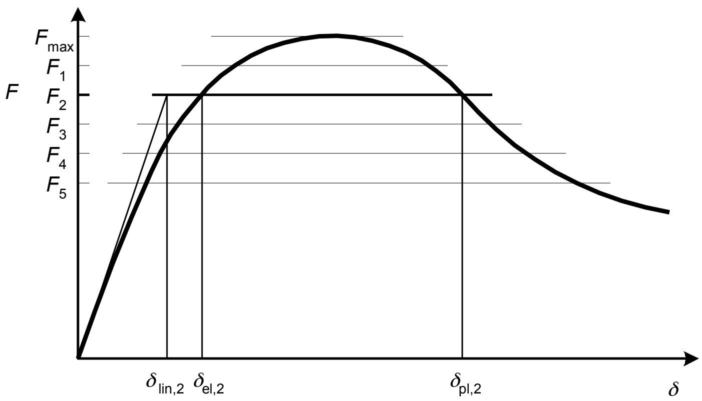


Fig. 2.4.2 – Relation between load F and net deflection δ

The failure mode observed was the same for profile without and with embossments and indentations. In all tests failure occurred by plastic deformation of the webs (web-crippling).

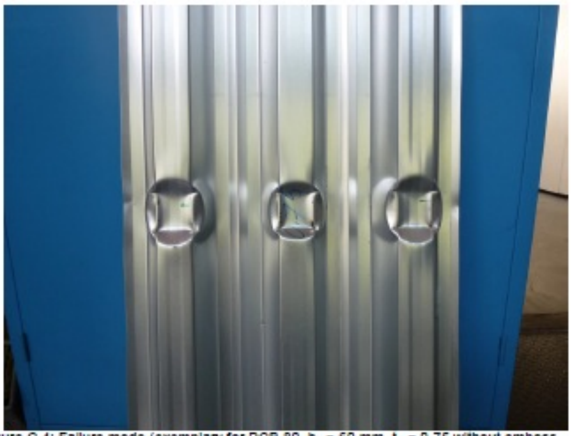


Figure C.4: Failure mode (exemplary for PCB 80, b_u = 60 mm, t_N = 0.75 without emboss-ments)

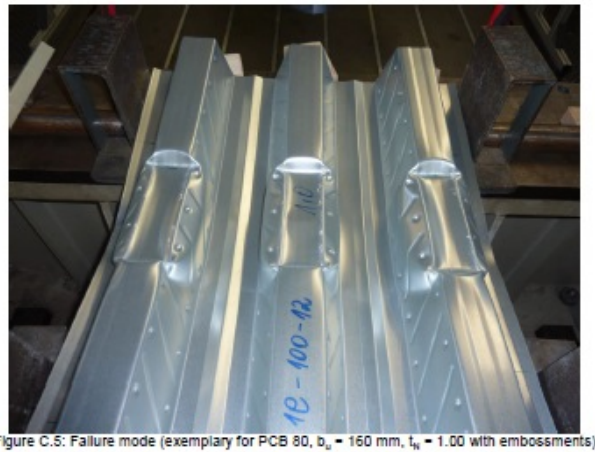


Figure C.5: Failure mode (exemplary for PCB 80, b_u = 160 mm, t_N = 1.00 with embossments)

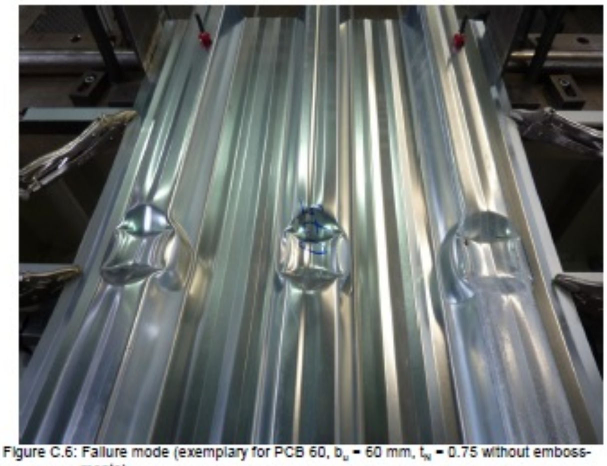


Figure C.6: Failure mode (exemplary for PCB 60, b_u = 60 mm, t_N = 0.75 without emboss-ments)

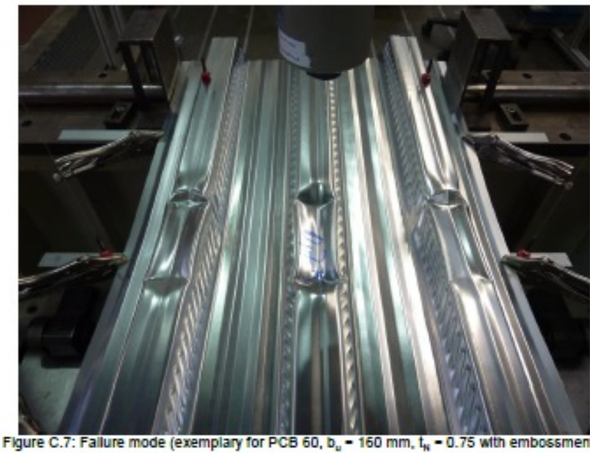


Figure C.7: Failure mode (exemplary for PCB 60, b_u = 160 mm, t_N = 0.75 with embossments)

Fig. 2.4.3 – Failure mode for PCB and PCB 80, with and without embossments

Reaction and Moment at support, for 1m width of profile:

PCB 80: t_{nom} = 0.75 mm and b_u = 60 mm

	PCB 80 0.75mm, b_u=60mm		
	without embossements	with embossements	
s	R_R	R_R	Embossment
m	kN/m	kN/m	influence
0,50	23,20	23,32	0,5%
1,10	14,83	15,03	1,4%
1,70	10,44	10,41	-0,3%

	PCB 80 0.75mm, b_u=60mm		
	without embossements	with embossements	
s	M_R	M_R	Embossment
m	kN.m/m	kN/m	influence
0,50	2,90	2,92	0,5%
1,10	4,09	4,14	1,4%
1,70	4,46	4,44	-0,3%

Interaction limite M-R

PCB 80 0.75mm, b_u=60mm without embossments

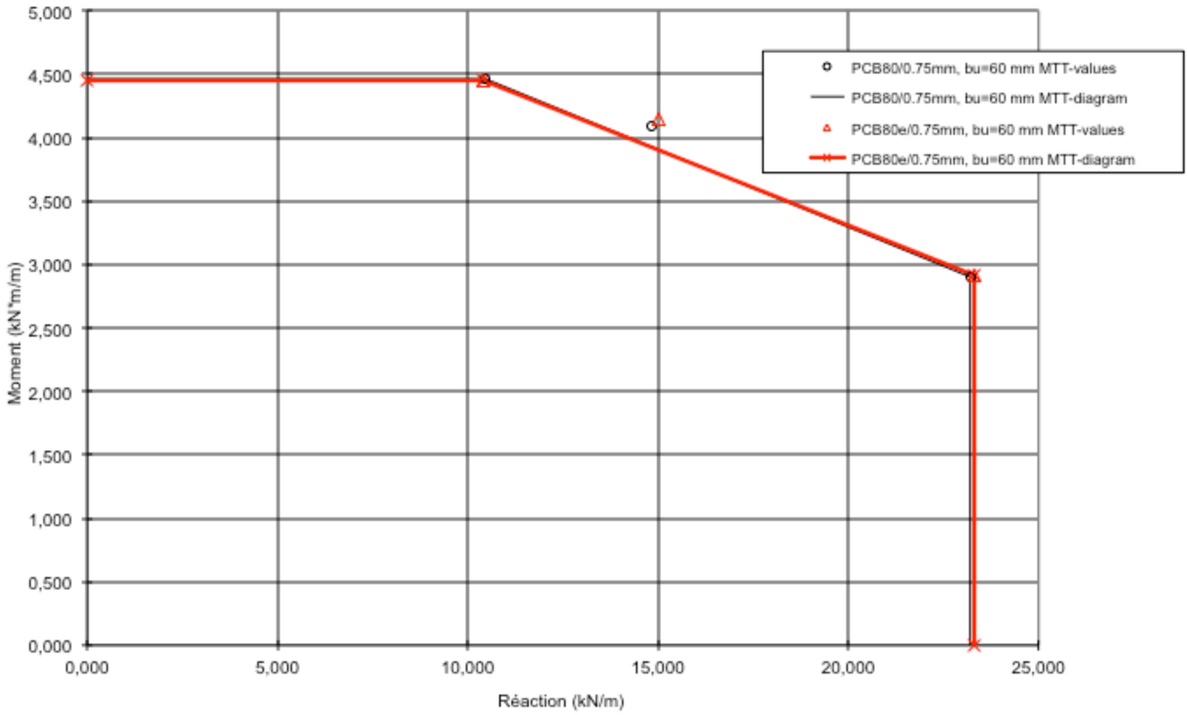
M_{Rk_max}	R_{Rk_min}
4,46	10,44

M_{Rk_min}	R_{Rk_max}
2,90	23,20

PCB 80 0.75mm, bu=60mm with embossments

M_{Rk_max}	R_{Rk_min}
4,44	10,41

M_{Rk_min}	R_{Rk_max}
2,92	23,32



PCB 80: t_{nom} = 0.75 mm and b_u = 160 mm

	PCB 80 0.75mm, b_u=160mm		
	without embossements	with embossements	
s m	R_R kN/m	R_R kN/m	Embossment influence
0,50	34,24	36,78	7,4%
1,10	19,02	20,21	6,3%
1,70	12,77	12,30	-3,7%

	PCB 80 0.75mm, b_u=160mm		
	without embossements	with embossements	
s m	M_R kN.m/m	M_R kN/m	Embossment influence
0,50	4,28	4,60	7,4%
1,10	5,24	5,57	6,2%
1,70	5,45	5,25	-3,7%

Interaction limite M-R

PCB 80 0.75mm, bu=160mm
without embossments

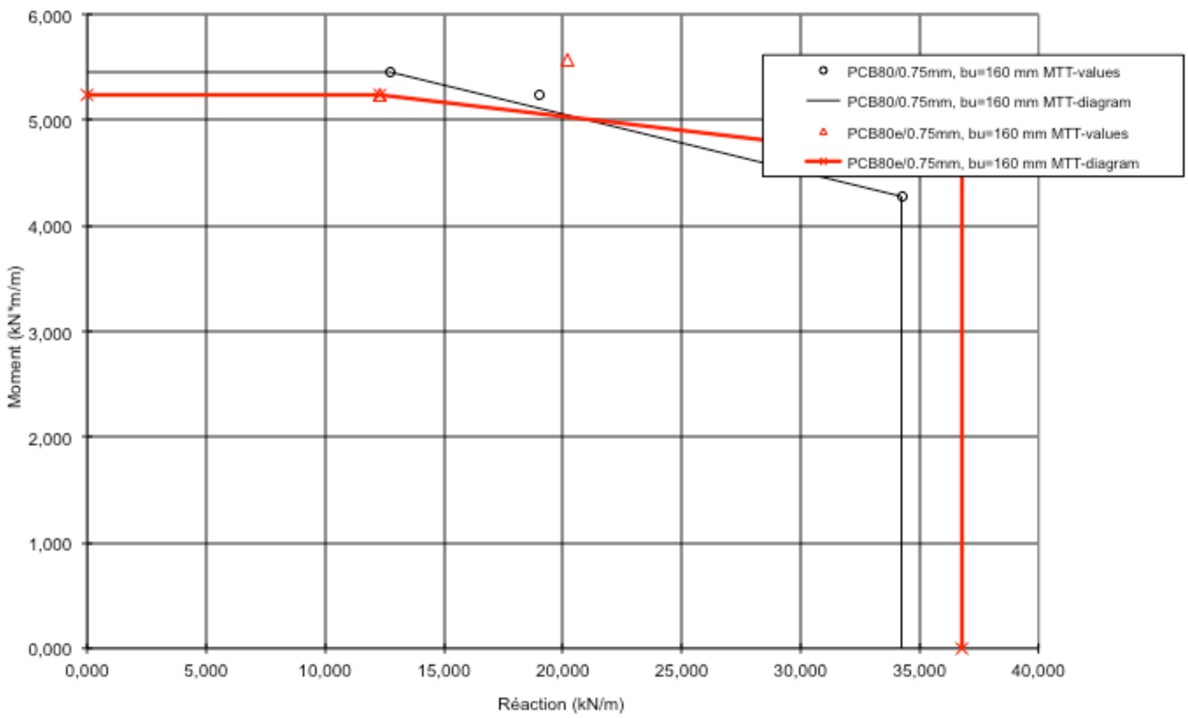
M_{Rk_max}	R_{Rk_min}
5,45	12,77

M_{Rk_min}	R_{Rk_max}
4,28	34,24

PCB 80 0.75mm, b_u=160mm
with embossments

M_{R_max}	R_{R_min}
5,25	12,30

M_{R_min}	R_{R_max}
4,60	36,78



PCB 80: t_{nom} = 1.00 mm and b_u = 60 mm

	PCB 80 1mm, b_u=60mm		
	without embossements	with embossements	
s m	R_R kN/m	R_R kN/m	Embossment influence
0,50	38,17	39,80	4,3%
1,10	24,33	24,22	-0,5%
1,70	17,13	17,21	0,4%

	PCB 80 1mm, b_u=60mm		
	without embossements	with embossements	
s m	M_R kN.m/m	M_R kN/m	Embossment influence
0,50	4,77	4,98	4,2%
1,10	6,70	6,67	-0,5%
1,70	7,31	7,34	0,4%

Interaction limite M-R

PCB 80 1mm, b_u=60mm
without embossments

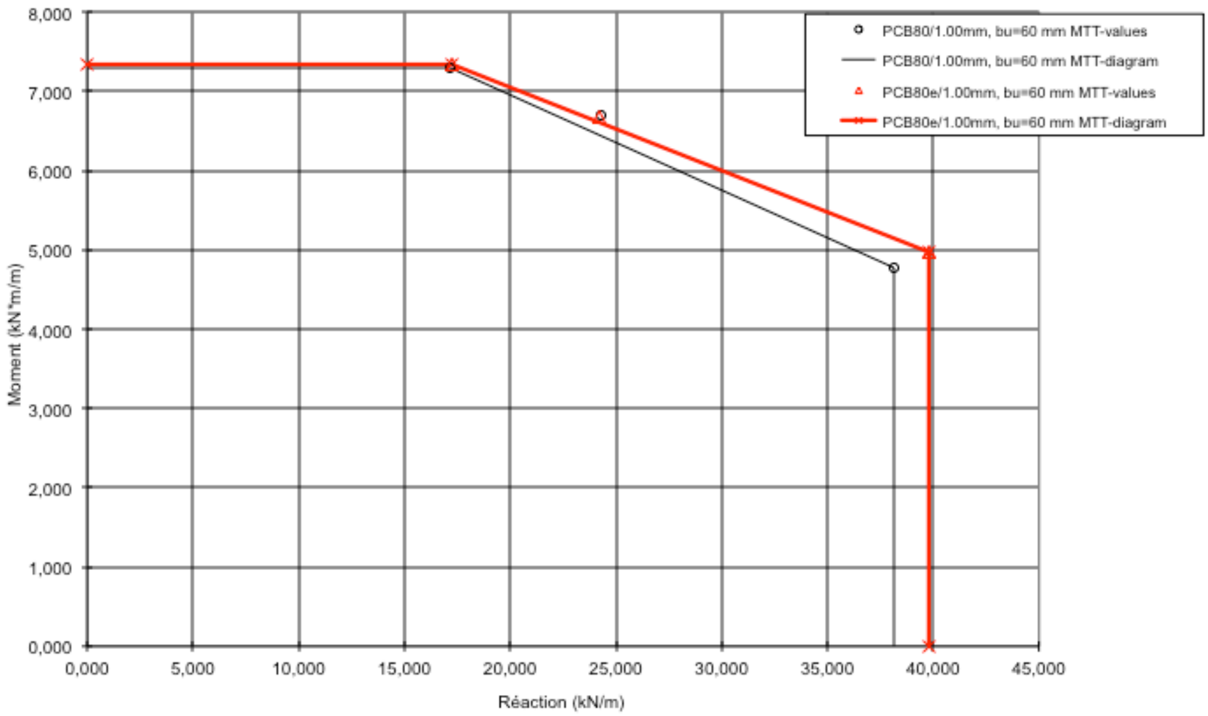
M_{Rk_max}	R_{Rk_min}
7,31	17,13

M_{Rk_min}	R_{Rk_max}
4,77	38,17

PCB 80 1mm, b_u=60mm
with embossments

M_{Rk_max}	R_{Rk_min}
7,34	17,21

M_{Rk_min}	R_{Rk_max}
4,98	39,80



PCB 80: t_{nom} = 1.00 mm and b_u = 160 mm

	PCB 80 1mm, b_u=160mm		
	without embossements	with embossements	
s	R_R	R_R	Embossment
m	kN/m	kN/m	influence
0,50	58,37	60,60	3,8%
1,10	31,47	32,27	2,6%
1,70	20,46	20,32	-0,7%

	PCB 80 1mm, b_u=160mm		
	without embossements	with embossements	
s	M_R	M_R	Embossment
m	kN.m/m	kN/m	influence
0,50	7,30	7,58	3,8%
1,10	8,66	8,89	2,5%
1,70	8,72	8,66	-0,7%

Interaction limite M-R

PCB 80 1mm, b_u=160mm without embossments

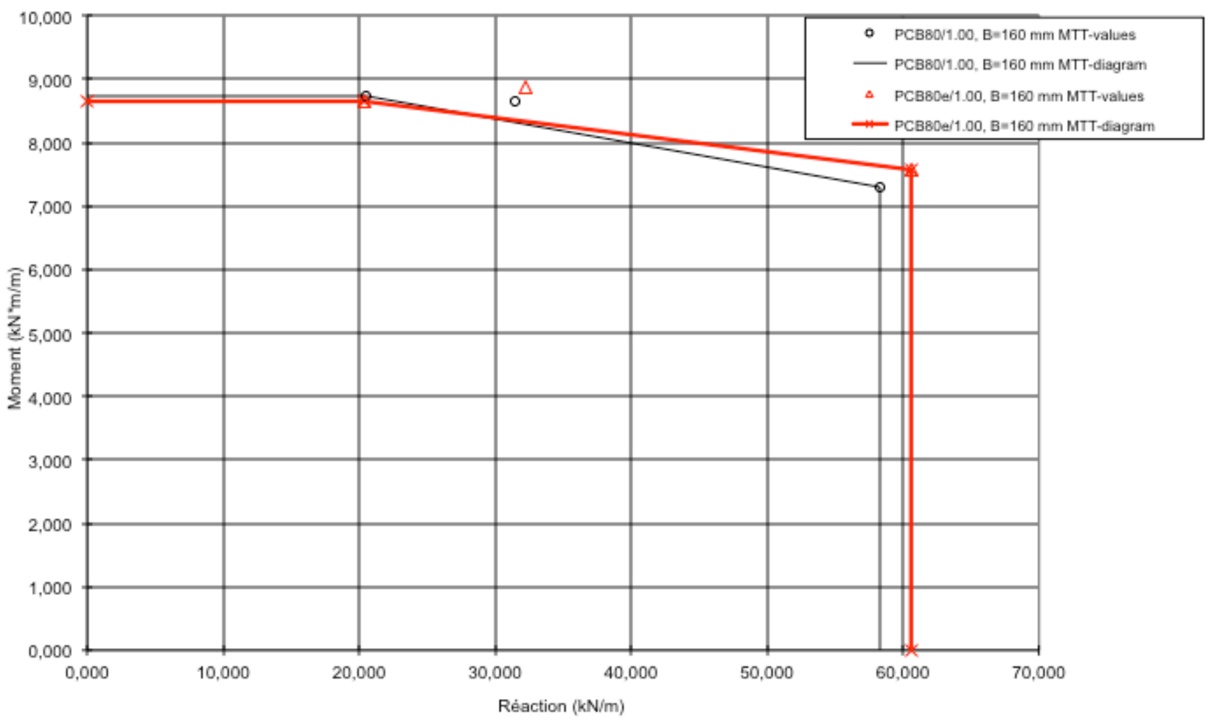
M_{Rk_max}	R_{Rk_min}
8,72	20,46

M_{Rk_min}	R_{Rk_max}
7,30	58,37

PCB 80 1mm, b_u=160mm with embossments

M_{Rk_max}	R_{Rk_min}
8,66	20,32

M_{Rk_min}	R_{Rk_max}
7,58	60,60



PCB 60: t_{nom} = 0.75 mm and b_u = 60 mm

	PCB 60 0.75mm, b_u=60mm		
	without embossements	with embossements	
s	R_R	R_R	Embossment
m	kN/m	kN/m	influence
0,40	20,24	20,46	1,1%
0,95	13,67	12,87	-5,9%
1,50	9,53	9,20	-3,5%

	PCB 60 0.75mm, b_u=60mm		
	without embossements	with embossements	
s	M_R	M_R	Embossment
m	kN.m/m	kN/m	influence
0,40	2,03	2,05	1,0%
0,95	3,25	3,06	-5,9%
1,50	3,59	3,46	-3,4%

Interaction limite M-R

PCB 60 0.75mm, b_u=60mm
without embossments

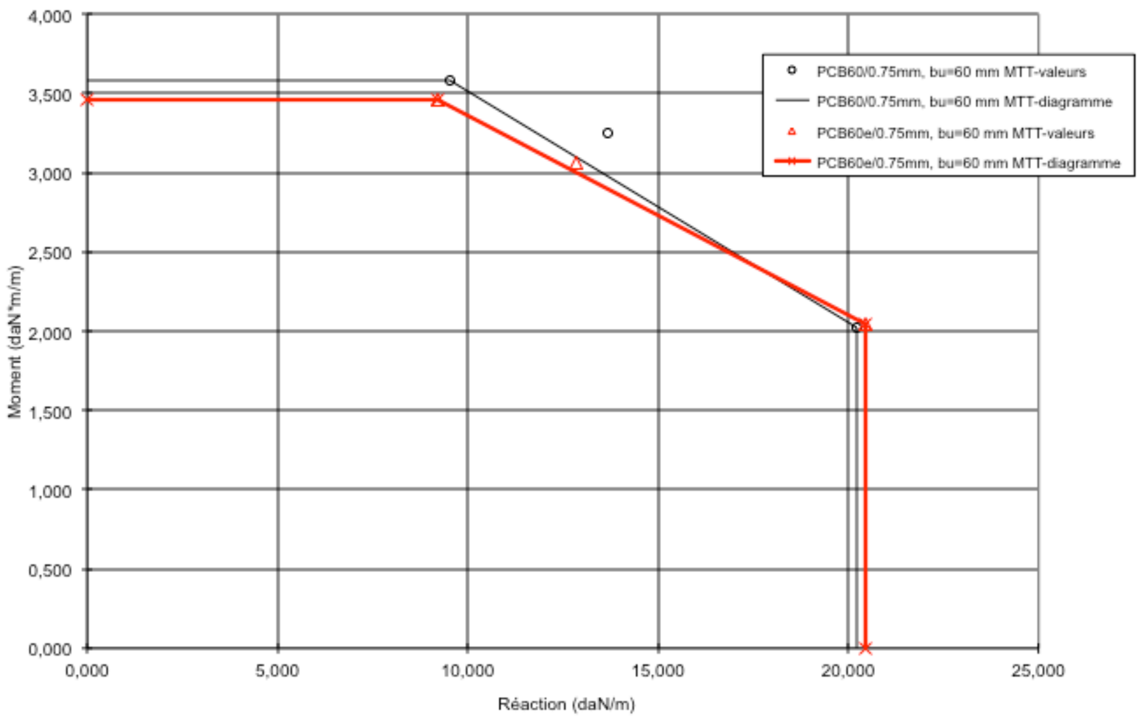
M_{Rk_max}	R_{Rk_min}
3,59	9,53

M_{Rk_min}	R_{Rk_max}
2,03	20,24

PCB 60 0.75mm, b_u=60mm
with embossments

M_{Rk_max}	R_{Rk_min}
3,46	9,20

M_{Rk_min}	R_{Rk_max}
2,05	20,46



PCB 60: t_{nom} = 0.75 mm and b_u = 160 mm

	PCB 60 0.75mm, b_u=160mm		
	without embossements	with embossements	
s	R_R	R_R	Embossment
m	kN/m	kN/m	influence
0,40	31,70	32,97	4,0%
0,95	18,81	16,74	-11,0%
1,50	11,89	11,05	-7,1%

	PCB 60 0.75mm, b_u=160mm		
	without embossements	with embossements	
s	M_R	M_R	Embossment
m	kN.m/m	kN/m	influence
0,40	3,17	3,30	4,0%
0,95	4,47	3,98	-11,0%
1,50	4,47	4,16	-7,0%

Interaction limite M-R

PCB 60 0.75mm, b_u=160mm
without embossments

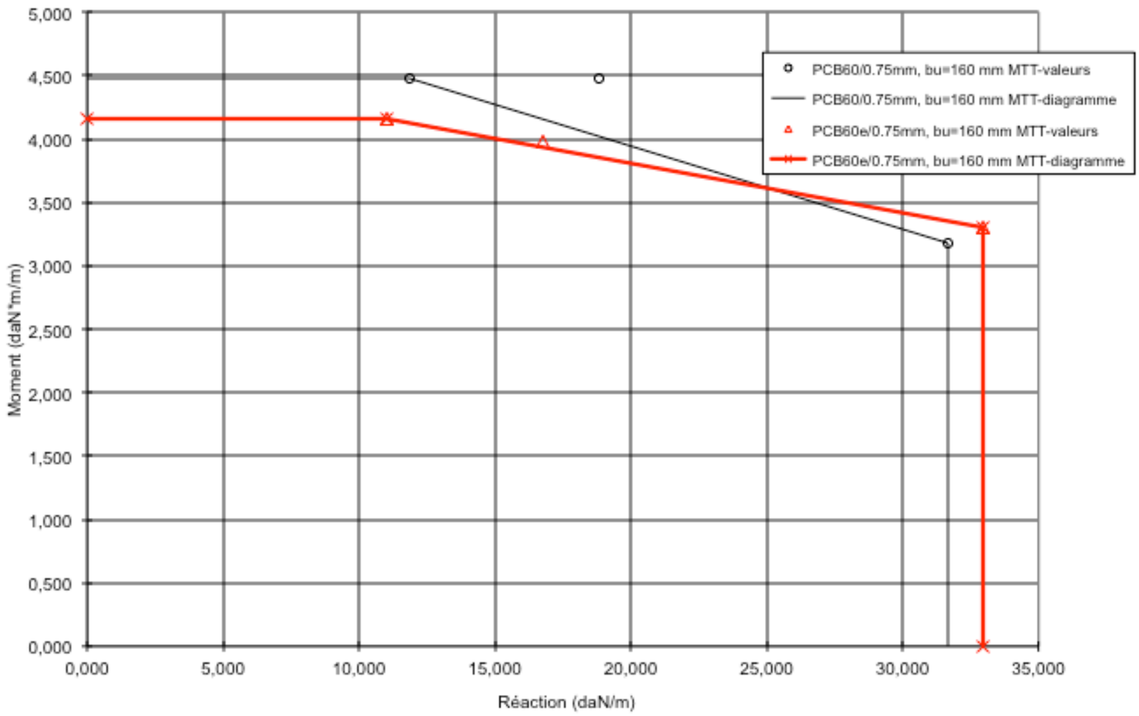
M_{Rk_max}	R_{Rk_min}
4,47	11,89

M_{Rk_min}	R_{Rk_max}
3,17	31,70

PCB 60 0.75mm, b_u=160mm
with embossments

M_{Rk_max}	R_{Rk_min}
4,16	11,05

M_{Rk_min}	R_{Rk_max}
3,30	32,97



PCB 60: t_{nom} = 1.00 mm and b_u = 60 mm

	PCB 60 1.00mm, b_u=60mm		
	without embossements	with embossements	
s m	R_R kN/m	R_R kN/m	Embossment influence
0,40	31,88	31,96	0,2%
0,95	21,05	20,29	-3,6%
1,50	15,17	14,36	-5,4%

	PCB 60 1.00mm, b_u=60mm		
	without embossements	with embossements	
s m	M_R kN.m/m	M_R kN.m/m	Embossment influence
0,40	3,19	3,20	0,2%
0,95	5,01	4,83	-3,6%
1,50	5,71	5,40	-5,4%

Interaction limite M-R

PCB 60 1.00mm, b_u=60mm
without embossments

M_{Rk_max}	R_{Rk_min}
5,71	15,17

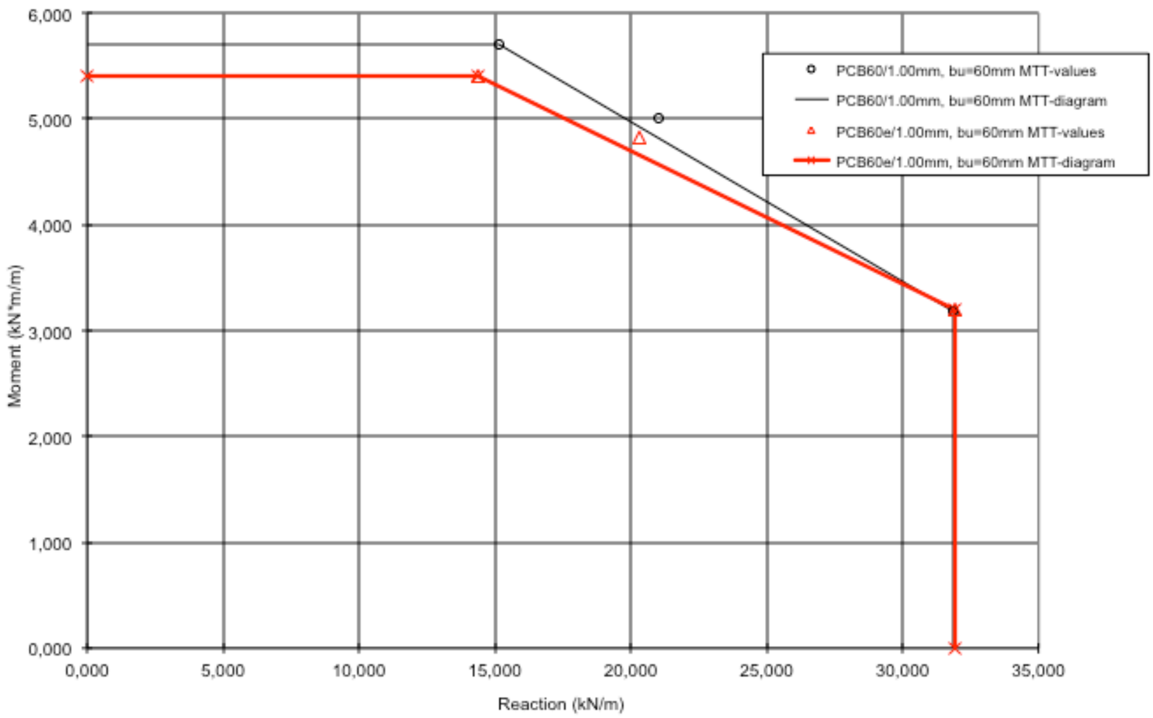
M_{Rk_min}	R_{Rk_max}
3,19	31,88

PCB 60 1.00mm, b_u=60mm
with embossments

M_{Rk_max}	R_{Rk_min}
5,40	14,36

M_{Rk_min}	R_{Rk_max}
3,20	31,96

2



<u>PCB 60:</u> t_{nom} = 1.00 mm and b_u = 160 mm

	PCB 60 1.00mm, b_u=160mm		
	without embossements	with embossements	
s	R_R	R_R	Embossment
m	kN/m	kN/m	influence
0,40	51,86	52,90	2,0%
0,95	29,20	27,07	-7,3%
1,50	18,46	17,26	-6,5%

	PCB 60 1.00mm, b_u=160mm		
	without embossements	with embossements	
s	M_R	M_R	Embossment
m	kN.m/m	kN.m/m	influence
0,40	5,19	5,29	2,0%
0,95	6,94	6,44	-7,3%
1,50	6,94	6,49	-6,5%

Interaction limite M-R

PCB 60 1.00mm, b_u=160mm
without embossments

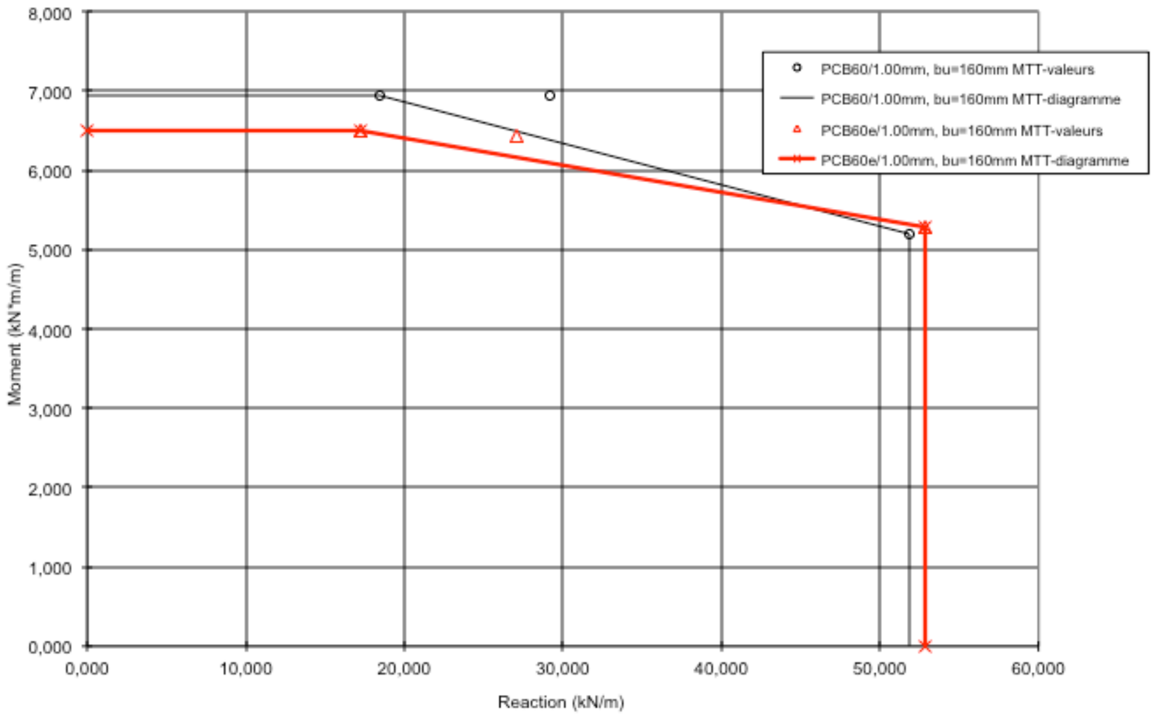
M_{Rk_max}	R_{Rk_min}
6,94	18,46

M_{Rk_min}	R_{Rk_max}
5,19	51,86

PCB 60 1.00mm, b_u=160mm
with embossments

M_{Rk_max}	R_{Rk_min}
6,49	17,26

M_{Rk_min}	R_{Rk_max}
5,29	52,90



The effect of combined action of support reaction and negative moment hasn't been studied up to now for sheeting without and with embossments and indentations. Therefore our study is the first one which allows to determine this effect and to quantify the influence of embossments and indentations based on 96 tests performed on intermediate support.

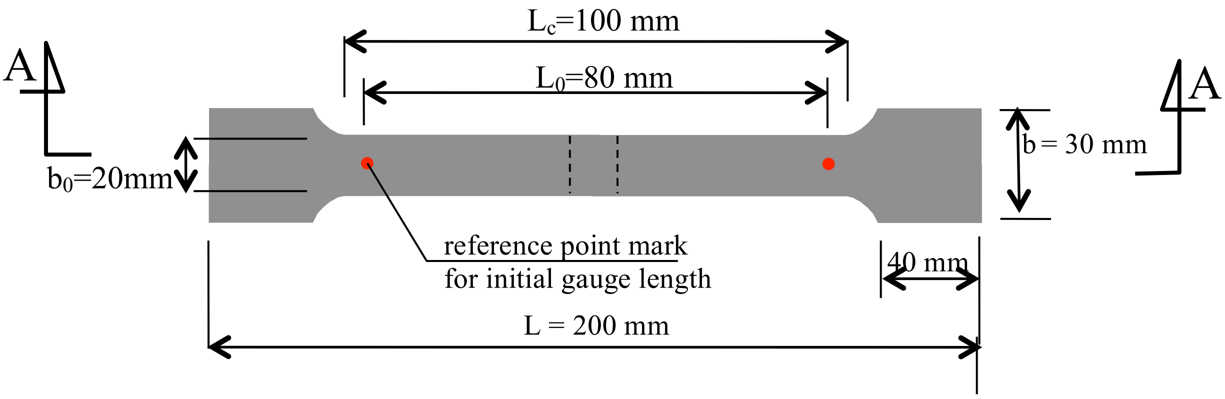
We can observe that:

- for smaller span s values, the interaction resistance of profile with embossments / indentations is equal or bigger than without embossment

- for bigger span s values, the interaction resistance of profile with embossments / indentations is equal or smaller than without embossment

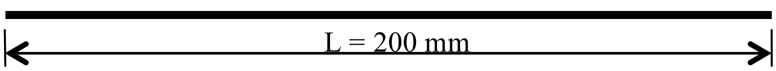
2.5 Testing on coupon tests

The tensile testing will be realized according to EN ISO 8692-1.



Section A-A

a) plate coupons



b) coupons with indentation

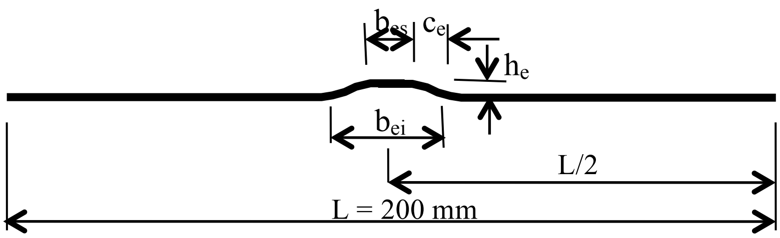


Fig. 2.5.1 Dimensions of coupons

Key:

L = total length

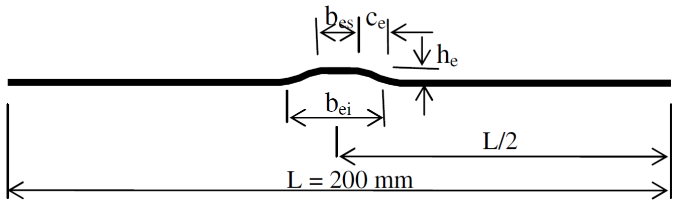
L_c = parallel length

L_0 = initial gauge length

b = total width

b_0 = width of the parallel reduced part

The dimensions of embossment b_{ei}, b_{es} and h_e are given in the Table 2.5.1 and 2.5.2



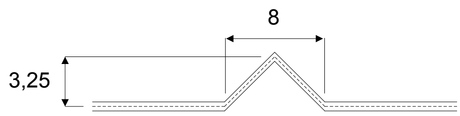
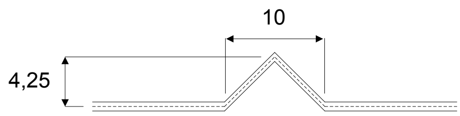
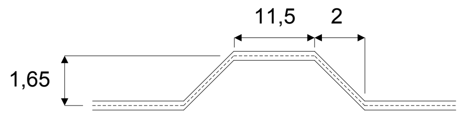
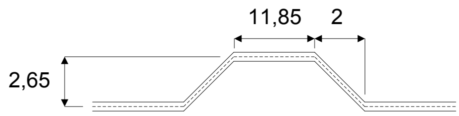
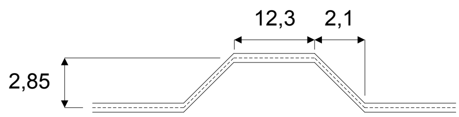
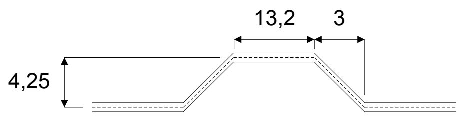
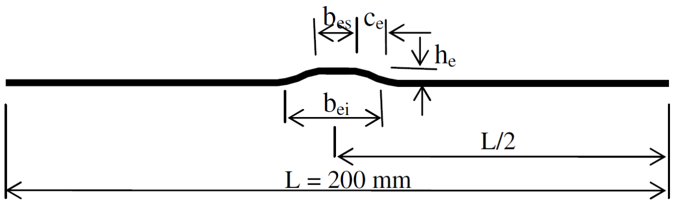
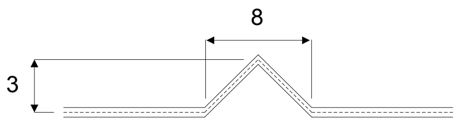
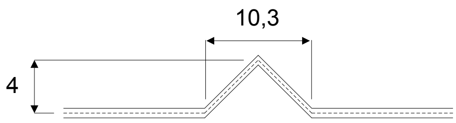
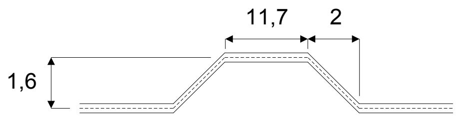
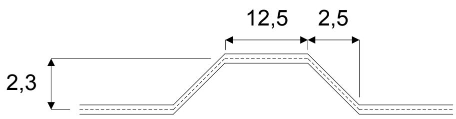
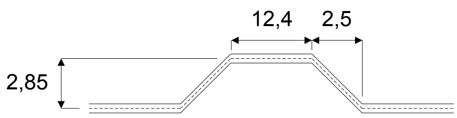
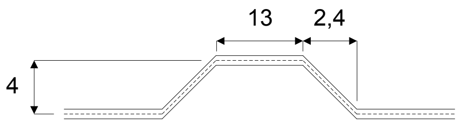
Test	Core thickness t_K [mm]	Measured height $h_e + t_N$ [mm]	Geometry according to Joris Ide [mm]
TT-e-075-0-0-0-1	0.698	-	
TT-e-075-0-0-0-2	0.701	-	
TT-e-075-0-0-0-3	0.702	-	
TT-e-075-1-1-0-1	0.701	2.14	-
TT-e-075-1-1-0-2	0.701	2.12	
TT-e-075-1-2-0-3	0.700	2.12	
TT-e-075-2-2-0-1	0.699	3.31	-
TT-e-075-2-2-0-2	0.705	3.25	
TT-e-075-2-2-0-3	0.702	3.30	
TT-e-075-3-3-0-1	0.694	4.00	
TT-e-075-3-3-0-2	0.698	3.96	
TT-e-075-3-3-0-3	0.679	3.94	
TT-e-075-4-4-0-1	0.701	4.85	
TT-e-075-4-4-0-2	0.700	4.85	
TT-e-075-4-4-0-3	0.696	4.91	
TT-e-075-1-1-10-1	0.693	2.40	
TT-e-075-1-1-10-2	0.699	2.41	
TT-e-075-1-1-10-3	0.695	2.40	
TT-e-075-2-2-10-1	0.699	3.39	
TT-e-075-2-2-10-2	0.699	3.35	
TT-e-075-2-2-10-3	0.700	3.34	
TT-e-075-3-3-10-1	0.698	3.57	
TT-e-075-3-3-10-2	0.698	3.57	
TT-e-075-3-3-10-3	0.702	3.56	
TT-e-075-4-4-10-1	0.691	5.06	
TT-e-075-4-4-10-2	0.699	5.11	
TT-e-075-4-4-10-3	0.698	5.10	

Table 2.5.1 Results of tensile tests with embossments, nominal thickness t_N = 0.75 mm



Test	Core thickness t_K [mm]	Measured height $h_e + t_N$ [mm]	Geometry according to Joris Ide [mm]
TT-e-100-0-0-0-1	0.934	-	
TT-e-100-0-0-0-2	0.931	-	
TT-e-100-0-0-0-3	0.934	-	
TT-e-100-1-1-0-1	0.935	2.31	-
TT-e-100-1-1-0-2	0.928	2.31	
TT-e-100-1-2-0-3	0.938	2.33	
TT-e-100-2-2-0-1	0.930	3.24	-
TT-e-100-2-2-0-2	0.933	3.25	
TT-e-100-2-2-0-3	0.935	3.24	
TT-e-100-3-3-0-1	0.931	4.00	
TT-e-100-3-3-0-2	0.934	3.96	
TT-e-100-3-3-0-3	0.927	3.94	
TT-e-100-4-4-0-1	0.930	4.85	
TT-e-100-4-4-0-2	0.934	4.85	
TT-e-100-4-4-0-3	0.933	4.91	
TT-e-100-1-1-10-1	0.934	2.40	
TT-e-100-1-1-10-2	0.927	2.41	
TT-e-100-1-1-10-3	0.934	2.40	
TT-e-100-2-2-10-1	0.928	3.39	
TT-e-100-2-2-10-2	0.933	3.35	
TT-e-100-2-2-10-3	0.934	3.34	
TT-e-100-3-3-10-1	0.934	3.57	
TT-e-100-3-3-10-2	0.931	3.57	
TT-e-100-3-3-10-3	0.928	3.56	
TT-e-100-4-4-10-1	0.934	5.06	
TT-e-100-4-4-10-2	0.933	5.11	
TT-e-100-4-4-10-3	0.934	5.10	

2.5.2 Results of tensile tests with embossments, nominal thickness t_N = 0.75 mm

Figure 2.5.2 shows all the stress-strain curves for thickness t_N = 0.75 mm

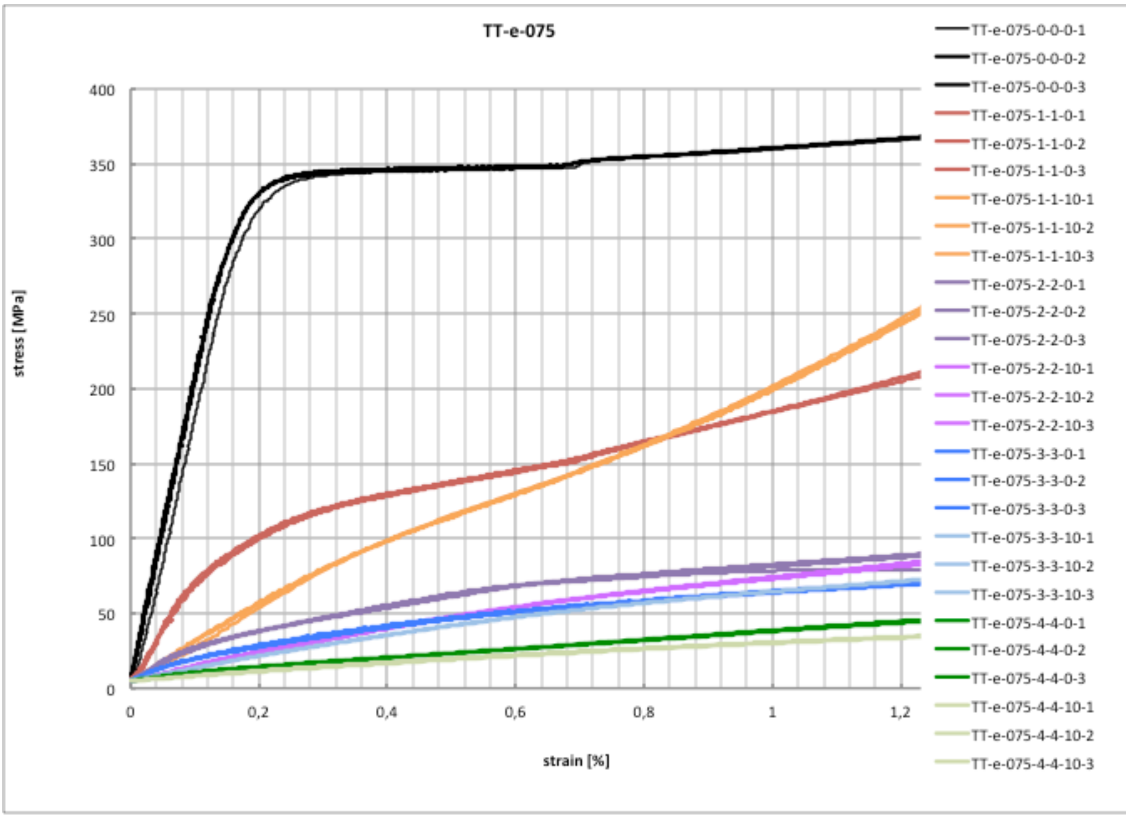


Fig. 2.5.2 – Stress-strain curves for thikness t_N = 0.75 mm

The stress decreases in accordance with the embossments. The more important the embossment is the more important the stress decrease is. The further detailed analysis will allow to determine the ratios between the yield stress of the coupon plate without embossment and the yield stress of the coupon plate with embossment.

3 CONCLUSION

A huge program of 152 tests was performed in order to determine and compare resistance values of steel decks without and with embossments and indentations or with outwards stiffener in the upper flange. It allowed us to conclude:

- for the moment resistance: the embossments and indentations decrease moment resistance from 3,5% up to 9,7%, and decrease inertia moment from 1,4% up to 10,7%. The study performed by P. Luure and M. Crisinel [1] which showed a decrease of about 10% on the resistance and the study performed by J. M. Davies [2] who found in his finite element analysis a decrease of 3 to 10% of the bending strength are consistent with our study.

- for the end support resistance (web crippling) the embossments and indentations increase the web crippling resistance from 5,5% up to 20,3%. P. Luure and M. Crisinel [1] found an increase of about 10%, which is consistent with our values.

- for the moment-reaction interaction, it is observed that in general tendency:
  - for smaller span s values, the interaction resistance of profile with embossments / indentations is equal or bigger than without embossment

- for bigger span s values, the interaction resistance of profile with embossments / indentations is equal or smaller than without embossment

This observation may be logically explained by the following:
- from end support and simply span tests it results that the embossments decrease the moment resistance and increase the reaction resistance
. for smaller s values (left side of the M-R diagram) the interaction resistance is governed by the reaction resistance (that is higher)
. - for bigger s values (right side of the M-R diagram) the interaction resistance is governed by the moment resistance (that is lower)

This logical result is comforting the way to further detailed analysis with a view to define the behaviour law of bending and reaction resistance of sections with embossments / indentations and outwards stiffeners.

REFERENCES

[1] P. LUURE AND M. CRISINEL "ESSAIS COMPARATIFS SUR TÔLES NERVUREES DE PLANCHERS MIXTES AVEC ET SANS BOSSAGES" 1993

[2] J. M. DAVIES, C. JIANG " DESIGN PROCEDURES FOR PROFILED METAL SHEETING AND DECKING", *THIN-WALLED STRUCTURES* VOL. 27, NO. I, PP. 43-53, 1997

[3] A. BIEGUS, D. CZEPIZAK " RESEARCH ON THE INTERACTIVE RESISTANCE OF CORRUGATED SHEETS UNDER COMBINED BENDING AND CONTACT PRESSURE", THIN-WALLED STRUCTURES 44, 825–831, 2006