GRISPE

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

Working Package 3

WP3 Test analysis and interpretation

30th August 2015

Deliverable D 3.4

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

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1. INTRODUCTION

1.1. Aim of the tests analysis and interpretation

For architectural reasons and also in order to improve the acoustic performance perforated profiles (Fig. 1.1.1), with different types, geometries and distribution of micro-perforations on the profile web and flange, are increasingly developed and used.

Fig. 1.1.1 - Trapezoidal sheet with perforated web (Montana Bausysteme AG, Villemergen [1])

European Standard EN 1993-1-3 dealing with design rules for cold-formed members and sheeting covers only the triangular distribution of such perforations while many exist on the market.

As far as round or square holes in the flange of sheeting are concerned, they are often required for the passage of services (Fig. 1.1.2). But only plane walls without holes are covered by EN 1993-1-3.

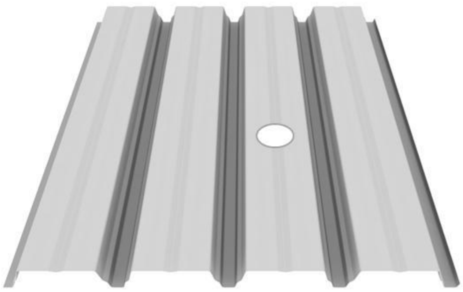


Fig. 1.1.2 - Round holes in the flange of sheeting

The background information about sheeting with holes only deals with buckling and postbuckling of plates with holes subjected to compression and shear loadings, and doesn't give any data about moment resistance, web crippling resistance and interaction moment-reaction resistance. As far as perforated sheeting with triangular and quadratic pattern perforations are concerned, some useful information found in the literature was given by Th. Misiek [2], [3], [4], investigations on the effective width and web crippling resistance. However, this investigation was based on numerical computer analysis that doesn't lead directly to the analytical formulation.

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 flange perforations, with web perforations and with total perforations
- to compare these values for sheeting without and with a circular or square single hole in the middle of the span

- to determine the effect sheeting flange perforations, web perforations, total perforations and circular or square single hole, on the structural behaviour: resistance and stiffness of the steel decks

1.2. General

A huge test program including 272 tests was performed on steel trapezoidal sheeting.

The profile PML 73 from JORIS IDE was tested without perforations and with triangular and square arrangement of perforations in the flange, in the web and in both flange and web

The profile PML 73 from JORIS IDE was tested without a hole and with a square or circular hole in the upper flange in the middle of the span.

The profile PML 56 from JORIS IDE was tested without a hole and with a square or circular hole in the upper flange in the middle of the span.

All the profiles were tested with two different thicknesses of the sheets 0,75 mm and 1 mm.

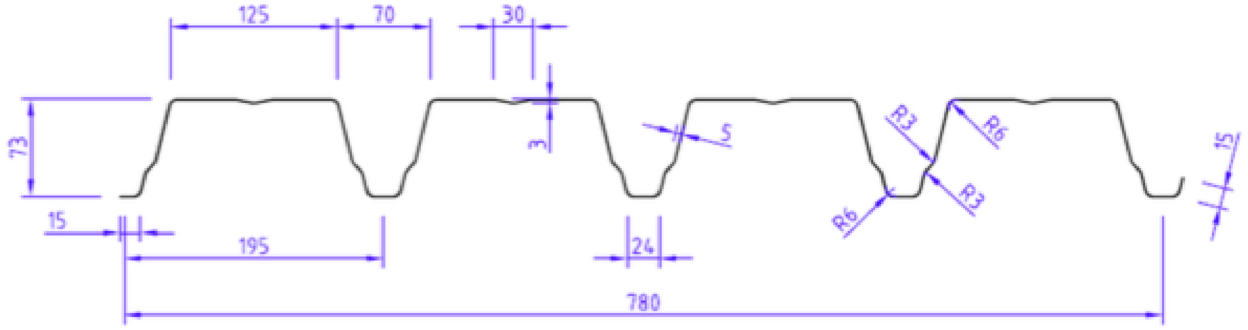


Fig. 1.2.1: PCB 73 from JORIS IDE

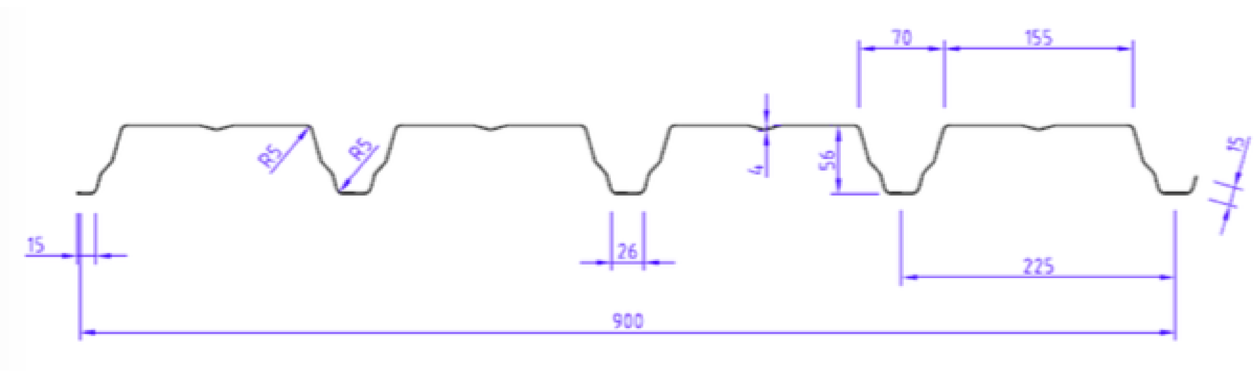


Fig. 1.2.2: PML 56 from JORIS IDE

The general behaviour of profiles was tested according to EN 1993-1-3, Annex A:
- single span tests for PML 73 and PML 56
- internal support tests for PML 73
- end support tests for PML 73

The local behaviour of sheets with perforations was tested on coupon tests.

2. RESISTANCE VALUES

2.1 Single span tests

<u>Tests set-up:</u>

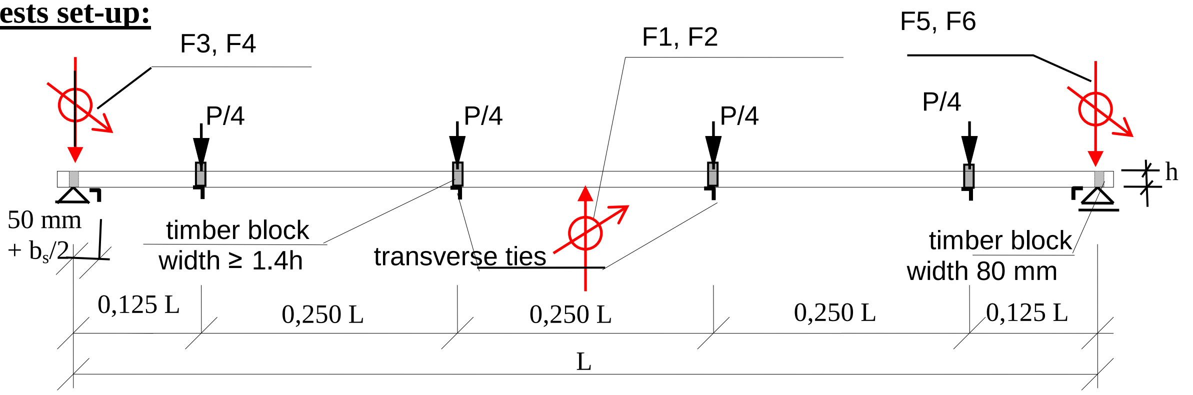


Fig. 2.1.1 – Test set-up for single span tests

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

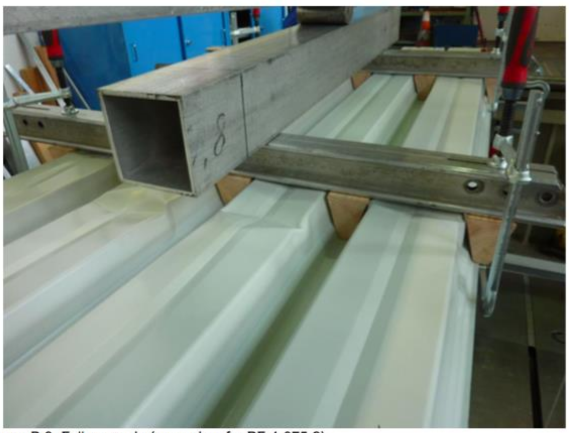


Figure B.3: Failure mode (exemplary for PF-4-075-2)

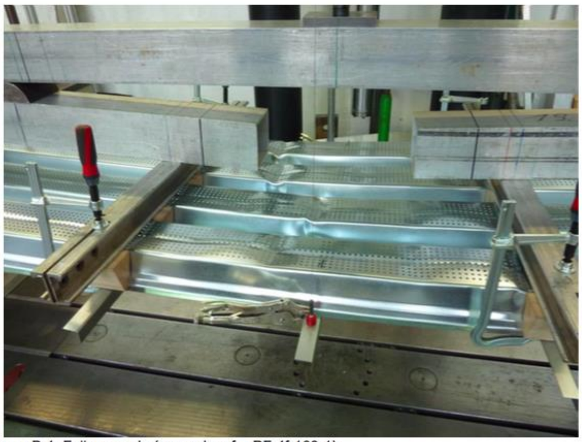


Figure B.4: Failure mode (exemplary for PF-4f-100-1)

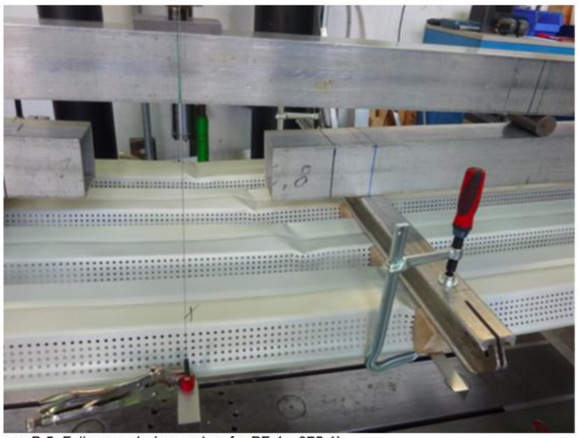


Figure B.5: Failure mode (exemplary for PF-4w-075-1)

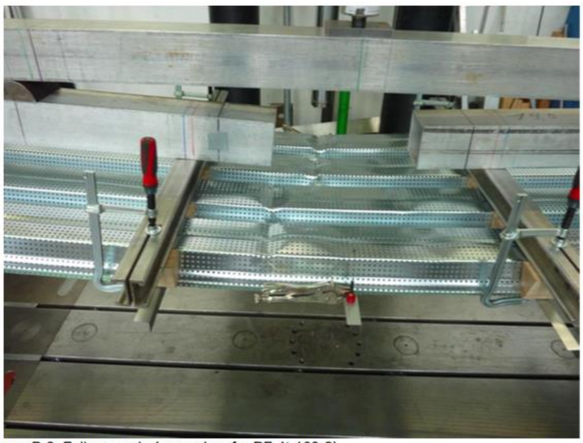


Figure B.6: Failure mode (exemplary for PF-4t-100-2)

Fig. 2.1.2 – Failure mode (PML 73, without perforations and with flange, web and total perforations)

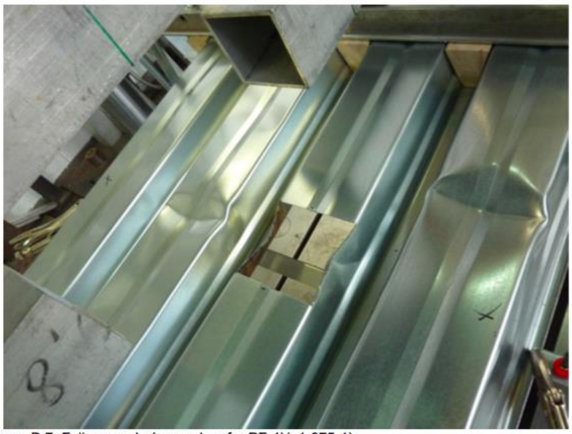


Figure B.7: Failure mode (exemplary for PF-4Hs1-075-1)

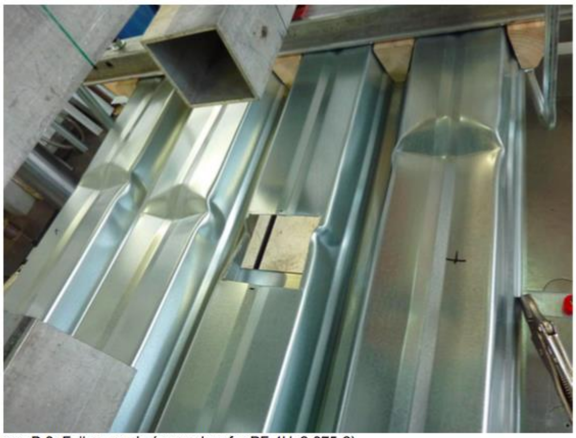


Figure B.8: Failure mode (exemplary for PF-4Hs2-075-2)

Figure B.9: Failure mode (exemplary for PF-4Hs3-075-1)

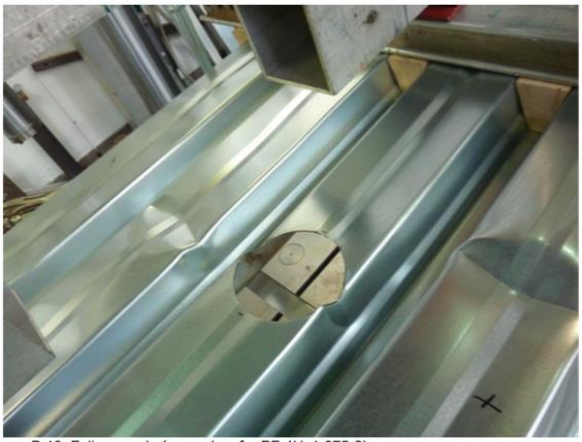


Figure B.10: Failure mode (exemplary for PF-4Hc1-075-2)

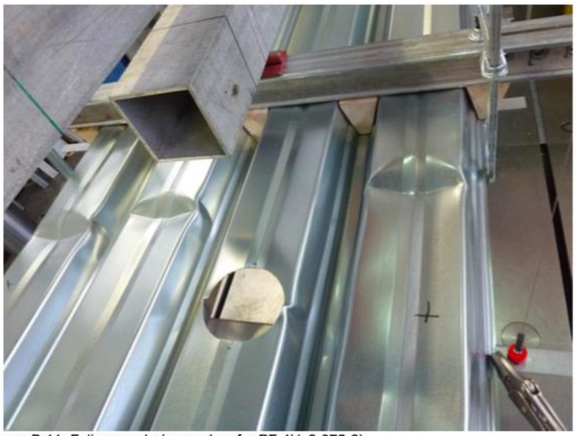


Figure B.11: Failure mode (exemplary for PF-4Hc2-075-2)

Figure B.12: Failure mode (exemplary for PF-4Hc3-075-1)

Fig. 2.1.3 – Failure mode (PML 73, with square and circular hole in the upper flange, in the middle of the span)

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

PML 73 without/with perforations:

PML 73	without perforation	flange perforation		web perforation		total perforation	
t_{nom}	M_{Rd}	M_{Rd}		M_{Rd}		M_{Rd}	
mm	kN*m/m	kN*m/m	influence	kN*m/m	influence	kN*m/m	influence
0,75	5,61	5,26	-6,2%	5,27	-6,1%	3,53	-37,1%
1,00	8,22	7,51	-8,6%	7,51	-8,6%	5,25	-36,1%

PML 73	without perforation	flange perforation		web perforation		total perforation	
t_{nom}	I_{eff}	I_{eff}		I_{eff}		I_{eff}	
mm	mm4/m	mm4/m	influence	mm4/m	influence	mm4/m	influence
0,75	673659	604301	-10,3%	611939	-9,2%	447062	-33,6%
1,00	892452	803998	-9,9%	795280	-10,9%	594836	-33,3%

PML 73 without/with circular hole:

PML 73	without hole	circular hole 1 d = 120 mm		circular hole 2 d = 105 mm		circular hole 3 d = 90 mm	
t_{nom}	M_{Rd}	M_{Rd}		M_{Rd}		M_{Rd}	
mm	kN*m/m	kN*m/m	influence	kN*m/m	influence	kN*m/m	influence
0,75	4,98	4,23	-15,0%	4,59	-7,8%	4,64	-6,9%
1,00	8,05	7,01	-12,9%	7,59	-5,8%	7,60	-5,7%

PML 73	without hole	circular hole 1 d = 120 mm		circular hole 2 d = 105 mm		circular hole 3 d = 90 mm	
t_{nom}	I_{eff}	I_{eff}		I_{eff}		I_{eff}	
mm	mm4/m	mm4/m	influence	mm4/m	influence	mm4/m	influence
0,75	716780	681866	-4,9%	675465	-5,8%	690256	-3,7%
1,00	904213	888733	-1,7%	896462	-0,9%	904473	0,0%

PML 73 without/with square hole:

PML 73	without hole	square hole 1 d = 120 mm		square hole 2 d = 105 mm		square hole 3 d = 90 mm	
t_{nom}	M_{Rd}	M_{Rd}		M_{Rd}		M_{Rd}	
mm	kN*m/m	kN*m/m	influence	kN*m/m	influence	kN*m/m	influence
0,75	4,98	4,22	-15,3%	4,51	-9,5%	4,67	-6,2%
1,00	8,05	6,88	-14,5%	7,21	-10,5%	7,73	-4,0%

PML 73	without hole	square hole 1 d = 120 mm		square hole 2 d = 105 mm		square hole 3 d = 90 mm	
t_{nom}	I_{eff}	I_{eff}		I_{eff}		I_{eff}	
mm	mm4/m	mm4/m	influence	mm4/m	influence	mm4/m	influence
0,75	716780	649701	-9,4%	676880	-5,6%	693040	-3,3%
1,00	904213	866585	-4,2%	906850	0,3%	914859	1,2%

PML 56 without/with circular hole:

PML 56	without hole	circular hole 1 d = 100 mm		circular hole 2 d = 65 mm	
t_{nom}	M_{Rd}	M_{Rd}		M_{Rd}	
mm	kN*m/m	kN*m/m	influence	kN*m/m	influence
0,75	3,18	2,93	-7,6%	3,04	-4,4%
1,00	5,09	4,87	-4,4%	4,90	-3,9%

PML 56	without hole	circular hole 1 d = 100 mm		circular hole 2 d = 65 mm	
t_{nom}	I_{eff}	I_{eff}		I_{eff}	
mm	mm4/m	mm4/m	influence	mm4/m	influence
0,75	344972	337364	-2,2%	344556	-0,1%
1,00	457223	451880	-1,2%	439792	-3,8%

PML 56 without/with square hole:

PML 56	without hole	square hole 1 d = 100 mm		square hole 2 d = 65 mm	
t_{nom}	M_{Rd}	M_{Rd}		M_{Rd}	
mm	kN*m/m	kN*m/m	influence	kN*m/m	influence
0,75	3,18	2,97	-6,5%	2,97	-6,5%
1,00	5,09	4,83	-5,2%	4,84	-5,0%

PML 56	without hole	square hole 1 d = 100 mm		square hole 2 d = 65 mm	
t_{nom}	I_{eff}	I_{eff}		I_{eff}	
mm	mm4/m	mm4/m	influence	mm4/m	influence
0,75	345077	341601	-1,0%	342911	-0,6%
1,00	456848	440893	-3,5%	437312	-4,3%

Flange perforation and web perforation induce similar decrease. The resistant moment decreases from 6,2% to 8,6%, and inertia moment decreases from 9,2% to 10,9% for profiles with web or flange perforation. Total perforation (flange + web) induces much more decrease: from 36,1% to 37,1% for the moment resistance and from 33,3% to 33,6% for the inertia moment.

As far as PML 73 holes influence on resistant moment is concerned it’s quite similar for circular and square holes. For d=120mm the decrease due to holes is from 12,9% to 15,3% , for d=105mm the decrease is from 5,8 to 10,5%, for d=90mm the decrease is from 4 to 6,9%.
The influence of holes on inertia moment ranges from an increase of 1,2% to a decrease of 9,4%. The increase of 1.2% was obtained with the 90 mm square hole and may be only considered as being in the range of practical dispersion of the tests results.

PML 56 circular and square holes decrease the resistant moment from 3,9% to 7,6%, and the inertia moment from 0,1% to 4,3%

2.2 End support tests

Test set-up:

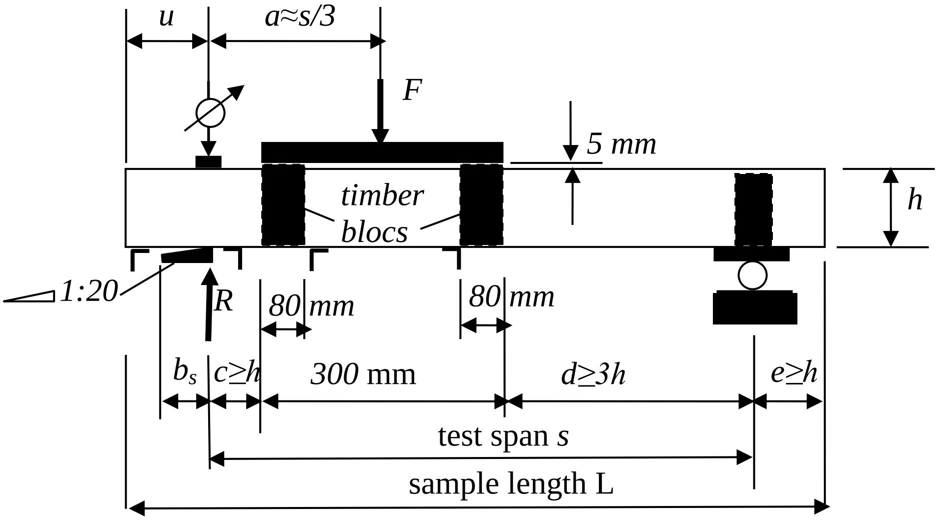


Fig. 2.2.1 – Test set-up for end support test

Web-crippling occurred in all profiles without and with perforations.

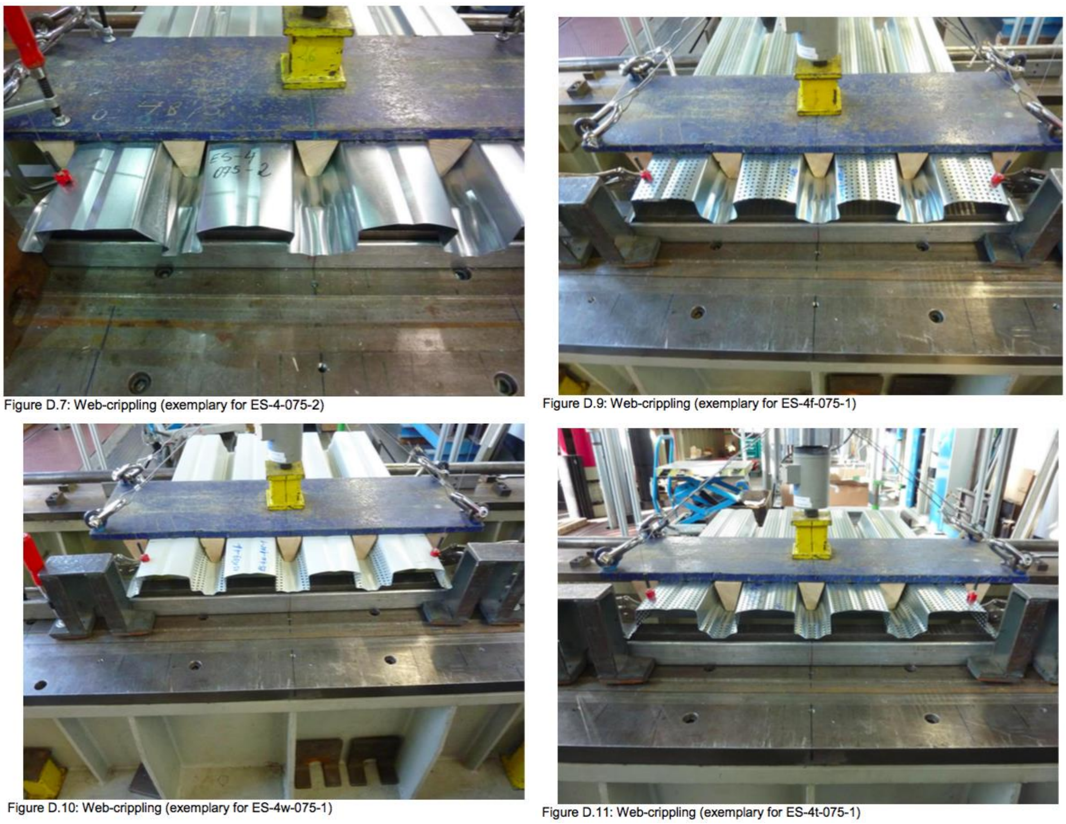


Fig. 2.2.2 – Web-crippling (PML 73, 1 mm without and with perforations)

Web crippling resistance for 1m of profile:

PML 73:

PML 73	without perforation	flange perforation		web perforation		total perforation	
t_{nom}	R_{Rd}	R_{Rd}		R_{Rd}		R_{Rd}	
mm	kN/m	kN/m	influence	kN/m	influence	kN/m	influence
0,75	23,18	22,88	-1,3%	17,53	-24,4%	15,08	-34,9%
1,00	38,30	36,79	-4,0%	27,32	-28,7%	23,60	-38,4%

We can observe that web crippling resistance is:

- slightly decreased by flange perforations (from 1,3% to 4%)
- significantly decreased by web perforations (from 24,4% to 28,7%)
- the most decreased by total perforations (from 34,9% to 38,4%)

2.3 Internal support tests

Test set-up:

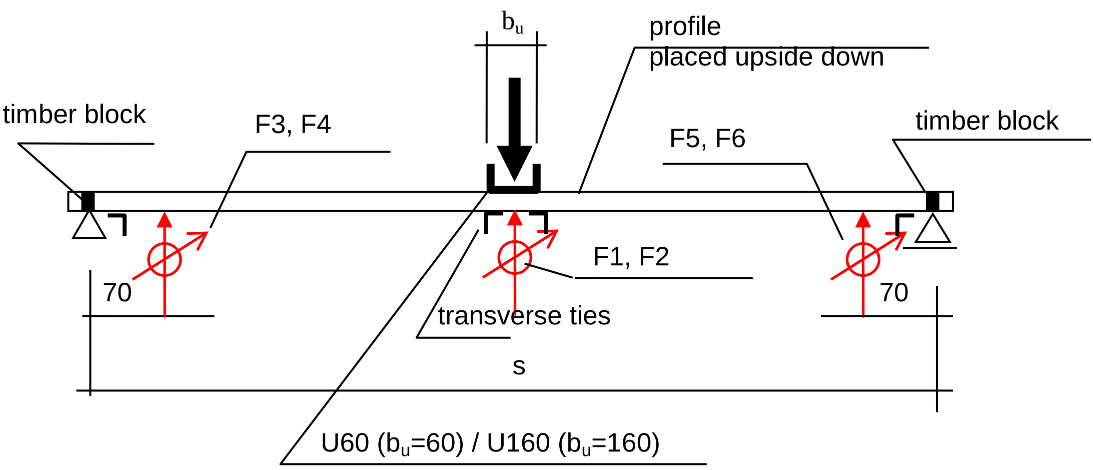


Fig. 2.3.1 – Test set-up for internal support tests

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

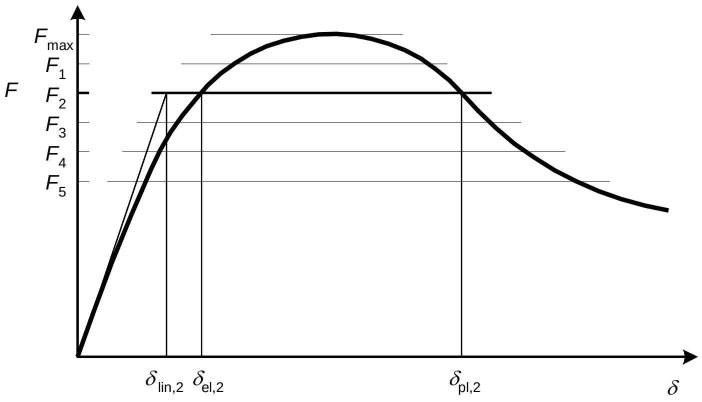


Fig. 2.3.2 – Relation between load F and net deflection δ

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

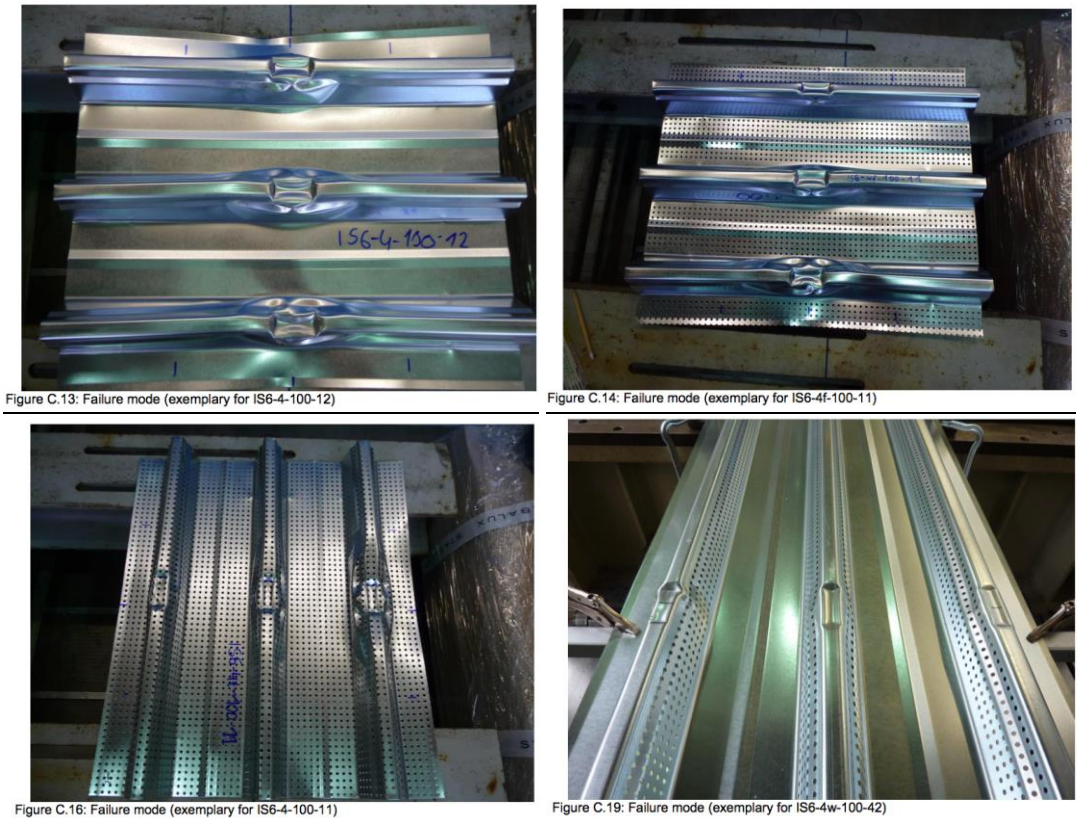


Fig. 2.3.3 – Failure mode for PML 73, with and without perforations

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

PML 73 t_{nom} = 0.75 mm and b_u = 60 mm

	PML 73 0.75mm, b_u=60mm						
	without perforation	flange perforation		web perforation		with total perforation	
s	R_R	R_R		R_R		R_R	
mm	kN/m	kN/m	influence	kN/m	influence	kN/m	influence
0,50	28,74	28,14	-2,1%	23,40	-18,6%	18,25	-36,5%
1,10	18,38			16,03	-12,8%	11,14	-39,4%
1,70	14,11	13,86	-1,7%	12,35	-12,5%	8,41	-40,4%

	PML 73 0.75mm, b_u=60mm						
	without perforation	flange perforation		web perforation		with total perforation	
s	M_R	M_R		M_R		M_R	
mm	kN.m/m	kN/m	influence	kN/m	influence	kN/m	influence
0,50	3,59	3,52	-2,1%	2,93	-18,6%	2,28	-36,5%
1,10	5,06			4,42	-12,8%	3,07	-39,3%
1,70	6,01	5,91	-1,7%	5,27	-12,5%	3,59	-40,3%

Interaction M-R

PML 73 0.75mm, b_u=60mm
without perforation

M_{Rk_max}	R_{Rk_min}
6,01	14,11

M_{Rk_min}	R_{Rk_max}
3,59	28,74

PML 73 0.75mm, b_u=60mm
flange perforation

M_{Rk_max}	R_{Rk_min}
5,91	13,86

M_{Rk_min}	R_{Rk_max}
3,52	28,14

PML 73 0.75mm, b_u=60mm
web perforation

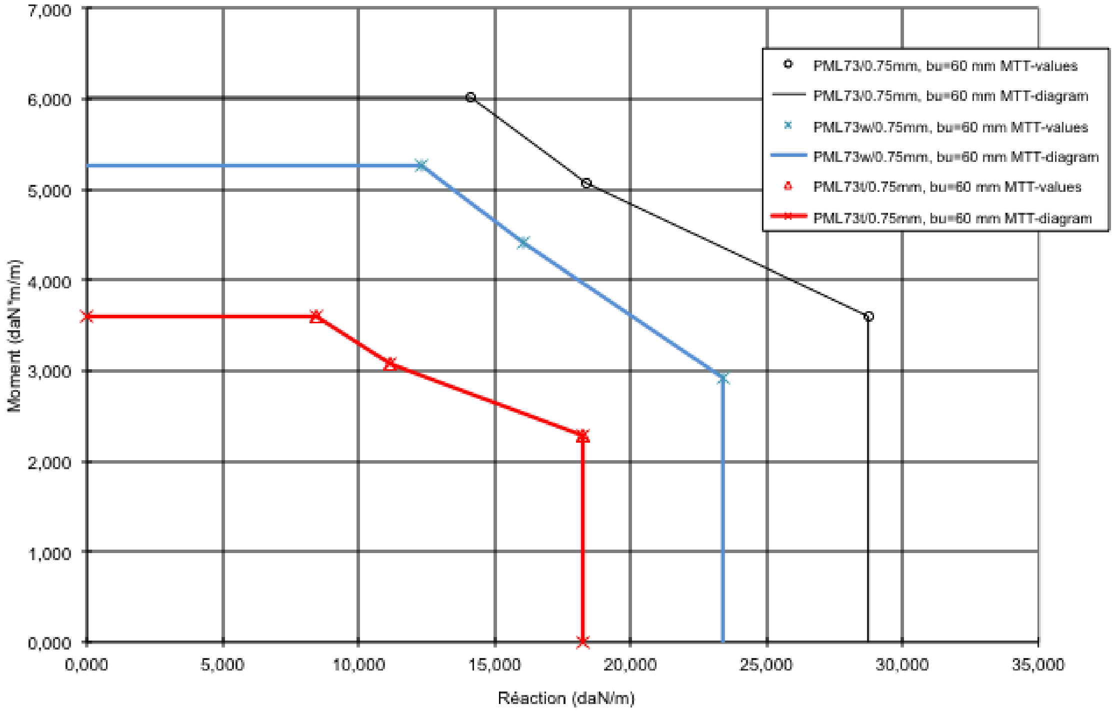
M_{Rk_max}	R_{Rk_min}
5,27	12,35

M_{Rk_min}	R_{Rk_max}
2,93	23,40

PML 73 0.75mm, bu=60mm
with total perforation

M_{Rk_max}	R_{Rk_min}
3,59	8,41

M_{Rk_min}	R_{Rk_max}
2,28	18,25



7,000
6,000
5,000
4,000
3,000
2,000
1,000
0,000
Moment (daN*m/m)
0,000
5,000
10,000
15,000
20,000
25,000
30,000
35,000
Réaction (daN/m)
PML73/0.75mm, bu=60 mm MTT-values
PML73/0.75mm, bu=60 mm MTT-diagram
PML73w/0.75mm, bu=60 mm MTT-values
PML73w/0.75mm, bu=60 mm MTT-diagram
PML73t/0.75mm, bu=60 mm MTT-values
PML73t/0.75mm, bu=60 mm MTT-diagram

<u>PML 73:</u> t_{nom} = 0.75 mm and b_u = 160 mm

	PML 73 0.75mm, b_u=160mm						
	without perforation	flange perforation		web perforation		with total perforation	
s mm	R_R kN/m	R_R kN/m	influence	R_R kN/m	influence	R_R kN/m	influence
0,50	39,80	40,28	1,2%	32,26	-18,9%	24,07	-39,5%
1,10	25,21			21,23	-15,8%	14,96	-40,7%
1,70	17,53	16,58	-5,4%	14,80	-15,6%	10,18	-41,9%

	PML 73 0.75mm, b_u=160mm						
	without perforation	flange perforation		web perforation		with total perforation	
s mm	M_R kN.m/m	M_R kN/m	influence	M_R kN/m	influence	M_R kN/m	influence
0,50	4,98	5,04	1,2%	4,03	-18,9%	3,01	-39,5%
1,10	6,94			5,85	-15,8%	4,12	-40,6%
1,70	7,47	7,06	-5,4%	6,31	-15,5%	4,34	-41,9%

Interaction M-R

PML 73 0.75mm, b_u=160mm
without perforation

M_{Rk_max}	R_{Rk_min}
7,47	17,53

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

PML 73 0.75mm, b_u=160mm
flange perforation

M_{Rk_max}	R_{Rk_min}
7,06	16,58

M_{Rk_min}	R_{Rk_max}
5,04	40,28

PML 73 0.75mm, b_u=160mm
web perforation

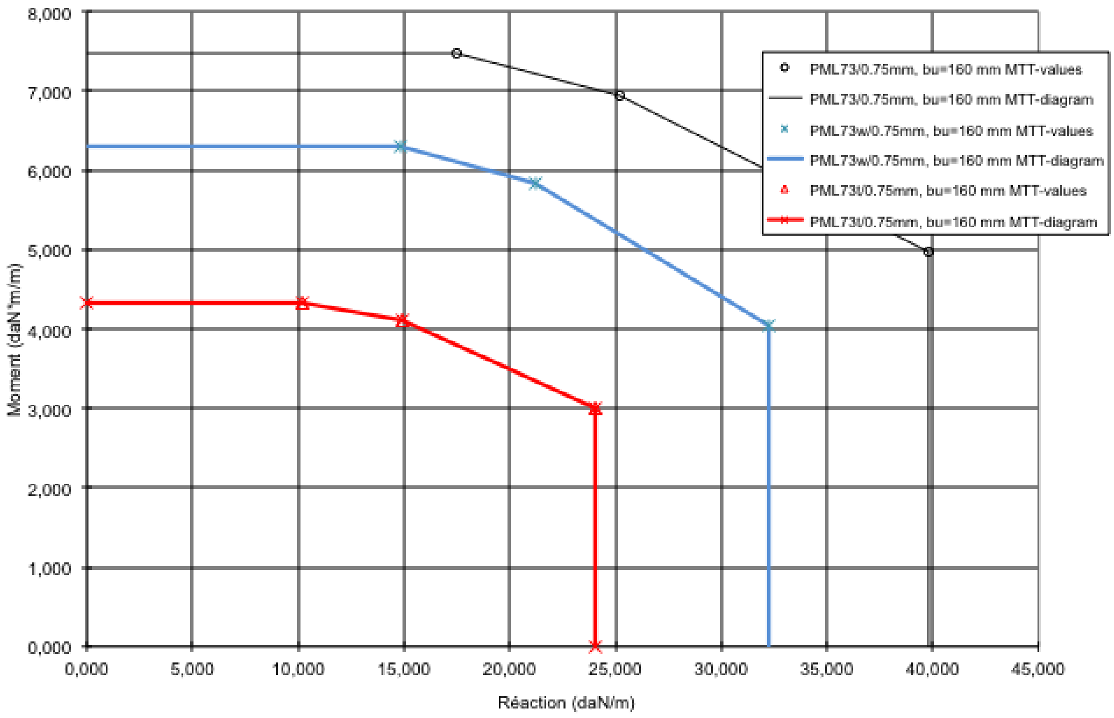
M_{Rk_max}	R_{Rk_min}
6,31	14,80

M_{Rk_min}	R_{Rk_max}
4,03	32,26

PML 73 0.75mm, bu=160mm
with total perforation

M_{Rk_max}	R_{Rk_min}
4,34	10,18

M_{Rk_min}	R_{Rk_max}
3,01	24,07



8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0,000
Moment (daN*m/m)
0,000
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
Réaction (daN/m)
PML73/0.75mm, bu=160 mm MTT-values
PML73/0.75mm, bu=160 mm MTT-diagram
PML73w/0.75mm, bu=160 mm MTT-values
PML73w/0.75mm, bu=160 mm MTT-diagram
PML73t/0.75mm, bu=160 mm MTT-values
PML73t/0.75mm, bu=160 mm MTT-diagram

PML 73: t_{nom} = 1.00 mm and b_u = 60 mm

	PML 73 1 mm, b_u=60mm						
	without perforation	flange perforation		web perforation		with total perforation	
s	R_R	R_R		R_R		R_R	
mm	kN/m	kN/m	influence	kN/m	influence	kN/m	influence
0,50	46,47	45,54	-2,0%	37,60	-19,1%	30,03	-35,4%
1,10	27,40			24,27	-11,4%	17,81	-35,0%
1,70	20,40	19,74	-3,2%	17,72	-13,1%	13,14	-35,6%

	PML 73 1 mm, b_u=60mm						
	without perforation	flange perforation		web perforation		with total perforation	
s	M_R	M_R		M_R		M_R	
mm	kN.m/m	kN/m	influence	kN/m	influence	kN/m	influence
0,50	5,81	5,69	-2,0%	4,70	-19,1%	3,75	-35,4%
1,10	7,55			6,69	-11,4%	4,91	-35,0%
1,70	8,70	8,41	-3,2%	7,55	-13,1%	5,61	-35,5%

Interaction M-R

PML 73 1 mm, b_u=60mm
without perforation

M_{Rk_max}	R_{Rk_min}
8,70	20,40

M_{Rk_min}	R_{Rk_max}
5,81	46,47

PML 73 1 mm, b_u=60mm
flange perforation

M_{Rk_max}	R_{Rk_min}
8,41	19,74

M_{Rk_min}	R_{Rk_max}
5,69	45,54

PML 73 1 mm, b_u=60mm
web perforation

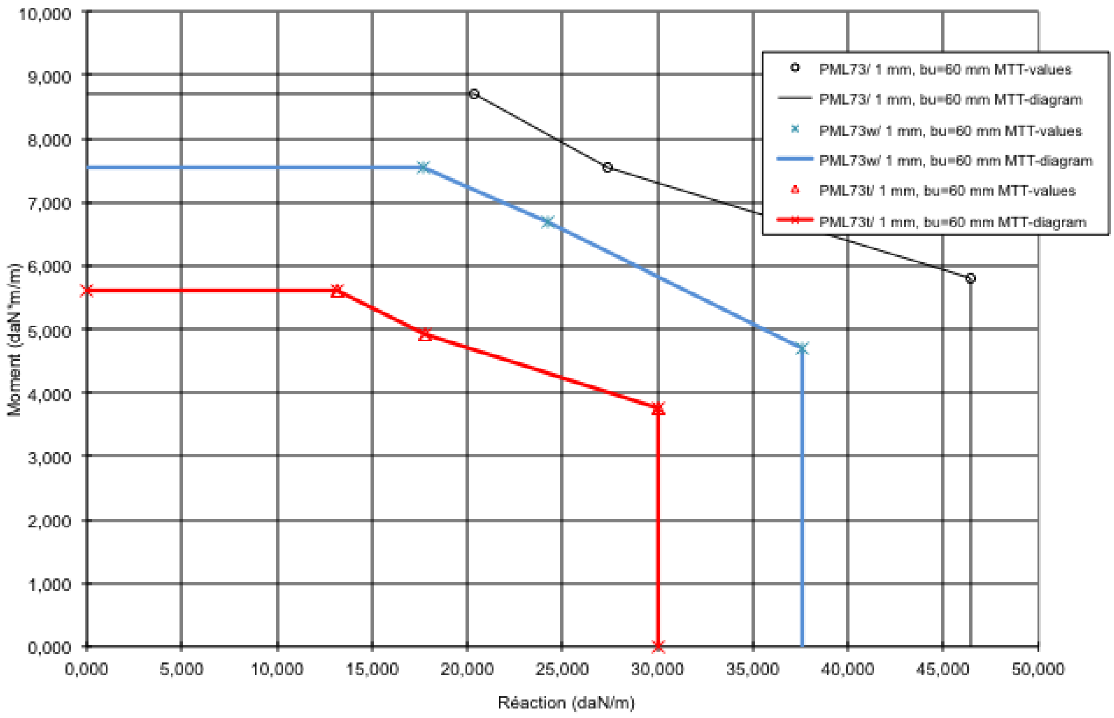
M_{Rk_max}	R_{Rk_min}
7,55	17,72

M_{Rk_min}	R_{Rk_max}
4,70	37,60

PML 73 1 mm, bu=60mm
with total perforation

M_{Rk_max}	R_{Rk_min}
5,61	13,14

M_{Rk_min}	R_{Rk_max}
3,76	30,03



10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0,000
Moment (daN*m/m)
0,000
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000
Réaction (daN/m)
PML73/ 1 mm, bu=60 mm MTT-values
PML73/ 1 mm, bu=60 mm MTT-diagram
PML73w/ 1 mm, bu=60 mm MTT-values
PML73w/ 1 mm, bu=60 mm MTT-diagram
PML73l/ 1 mm, bu=60 mm MTT-values
PML73l/ 1 mm, bu=60 mm MTT-diagram

PML 73: t_{nom} = 1.00 mm and b_u = 160 mm

	PML 73 1 mm, b_u=160mm						
	without perforation	flange perforation		web perforation		with total perforation	
s mm	R_R kN/m	R_R kN/m	influence	R_R kN/m	influence	R_R kN/m	influence
0,50	60,37	61,62	2,1%	50,93	-15,6%	39,26	-35,0%
1,10	36,33			30,87	-15,0%	23,00	-36,7%
1,70	24,69	23,94	-3,0%	21,12	-14,5%	15,59	-36,8%

	PML 73 1mm, b_u=160mm						
	without perforation	flange perforation		web perforation		with total perforation	
s mm	M_R kN.m/m	M_R kN/m	influence	M_R kN/m	influence	M_R kN/m	influence
0,50	7,55	7,70	2,1%	6,37	-15,6%	4,91	-35,0%
1,10	10,00			8,50	-15,0%	6,33	-36,7%
1,70	10,52	10,20	-3,0%	9,00	-14,4%	6,65	-36,8%

Interaction M-R

PML 73 1 mm, b_u=160mm
without perforation

M_{Rk_max}	R_{Rk_min}
10,52	24,69

M_{Rk_min}	R_{Rk_max}
7,55	60,37

PML 73 1 mm, b_u=160mm
flange perforation

M_{Rk_max}	R_{Rk_min}
10,20	23,94

M_{Rk_min}	R_{Rk_max}
7,70	61,62

PML 73 1 mm, b_u=160mm
web perforation

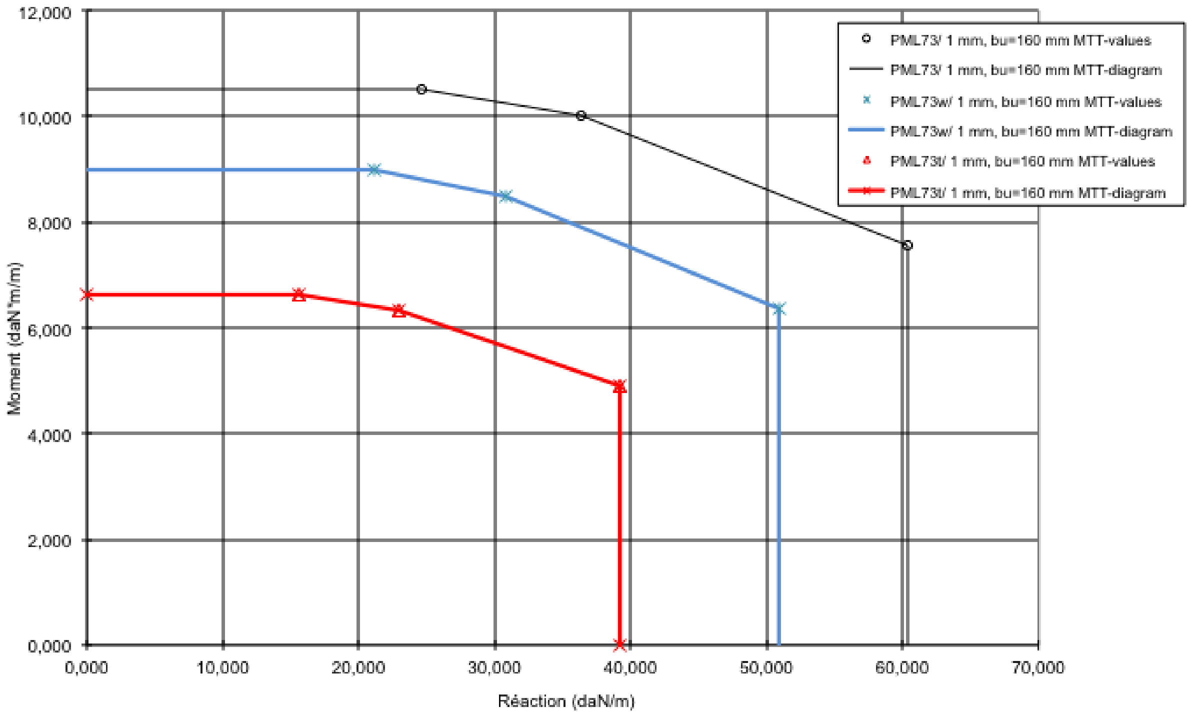
M_{Rk_max}	R_{Rk_min}
9,00	21,12

M_{Rk_min}	R_{Rk_max}
6,37	50,93

PML 73 1 mm, bu=160mm
with total perforation

M_{Rk_max}	R_{Rk_min}
6,65	15,59

M_{Rk_min}	R_{Rk_max}
4,91	39,26



Our study based on 80 tests performed at intermediate support allows to determine the effect and to quantify the influence of perforations.

The influence of flange perforations on support reaction and negative moment ranges from an increase of 2,1% to a decrease of 5,4%. The increased value is considered as being in the range of practical dispersion of the tests results and for the safety reason is considered as negligible.

The influence of web perforations is a decrease of support reaction and negative moment from 11,4% to 19,1%

Total perforation (flange + web) induces the bigger decrease of support reaction and negative moment from 35% to 41,9%

Therefore we can conclude that the interaction resistance of profile is decreased by web and total perforations

2.4 Tensile tests

The tests are performed on coupons:

a) without perforation
b) with perforation arranged in triangles
c) with perforation arranged in squares

The coupons will be tested according to EN ISO 6892-1.

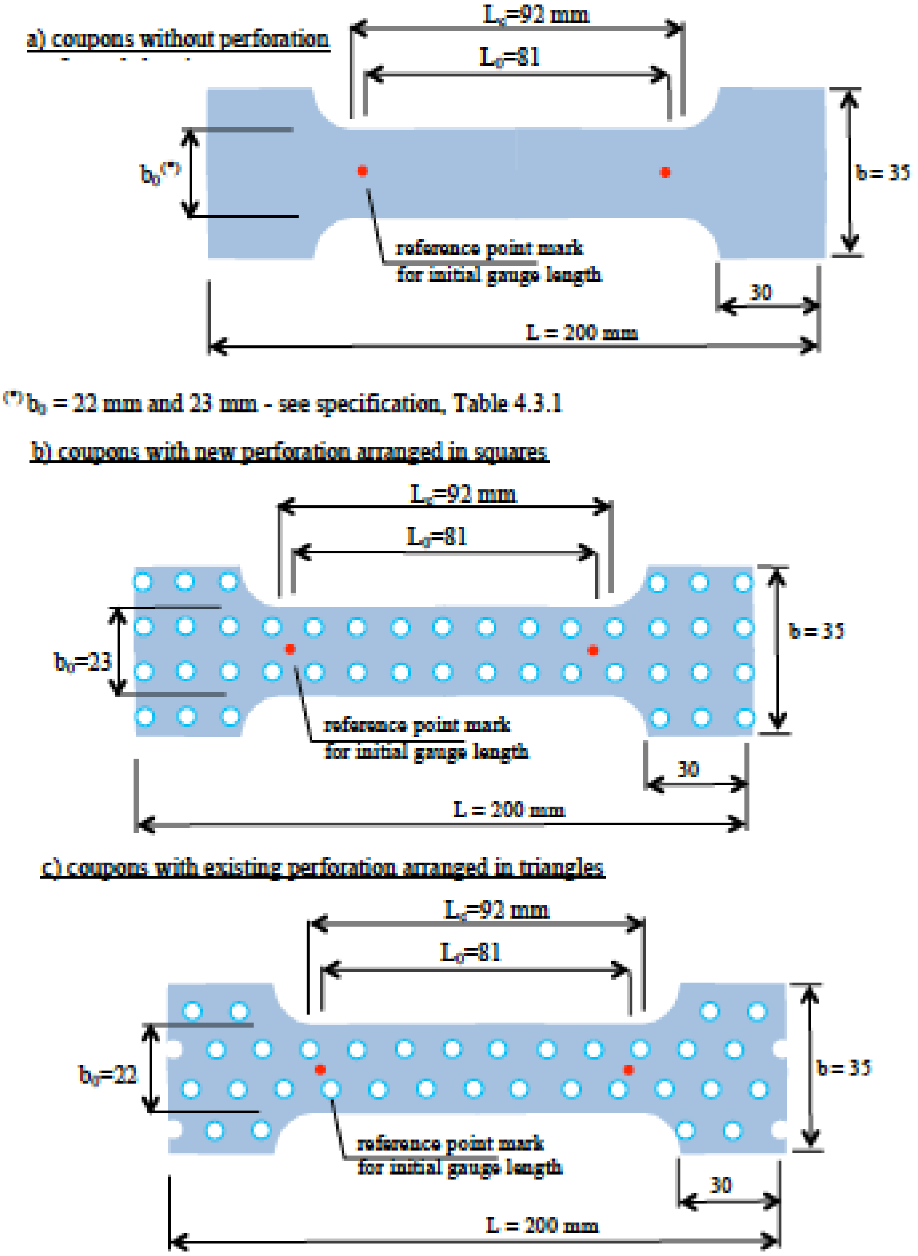


Fig. 3.2.1.1 Dimensions of coupons for tensile tests with perforated sheet

Figures 2.4.1 and 2.4.2 show all the stress-strain curves without and with perforations arranged in triangle.
Figures 2.4.3 and 2.4.4 show all the stress-strain curves without and with perforations arranged in square.

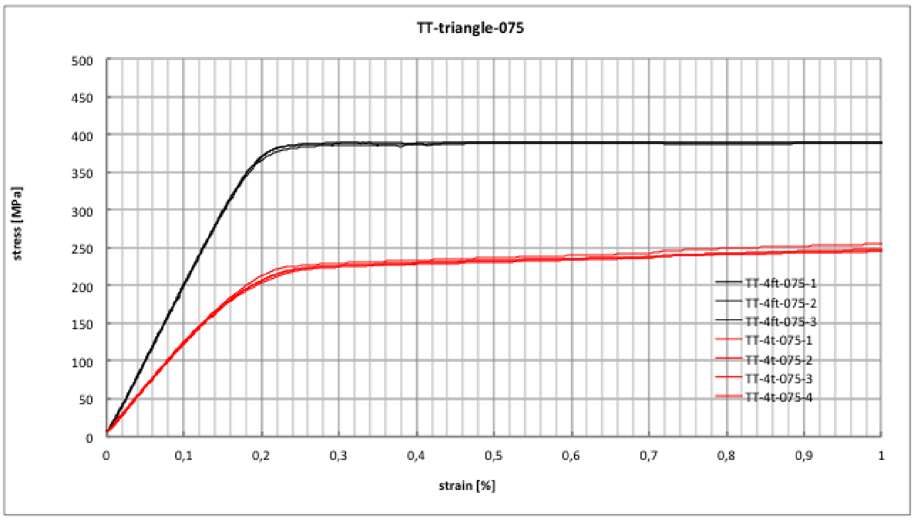


Fig. 2.4.1 – Stress-strain curves without (black curves) and with perforations (red curves) arranged in triangle for thickness t_N = 0.75 mm

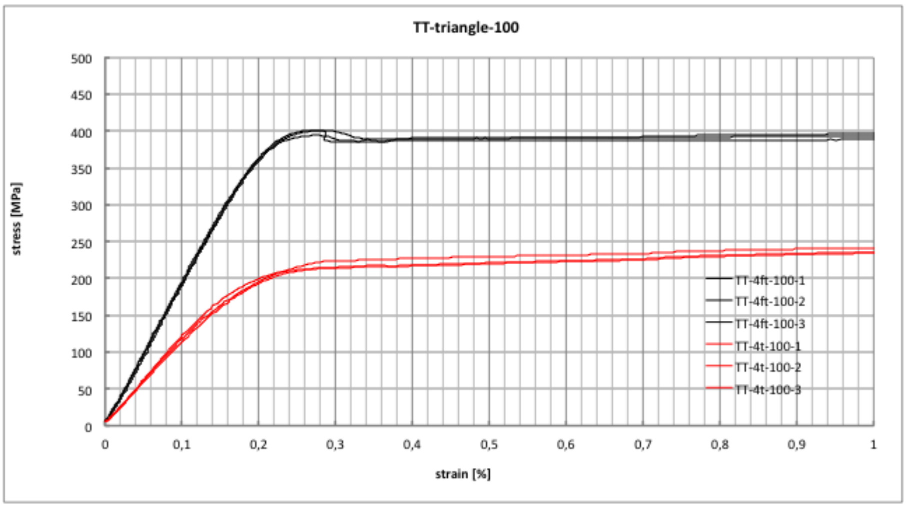


Fig. 2.4.2 – Stress-strain curves without (black curves) and with perforations (red curves) arranged in triangle for thickness t_N = 1 mm

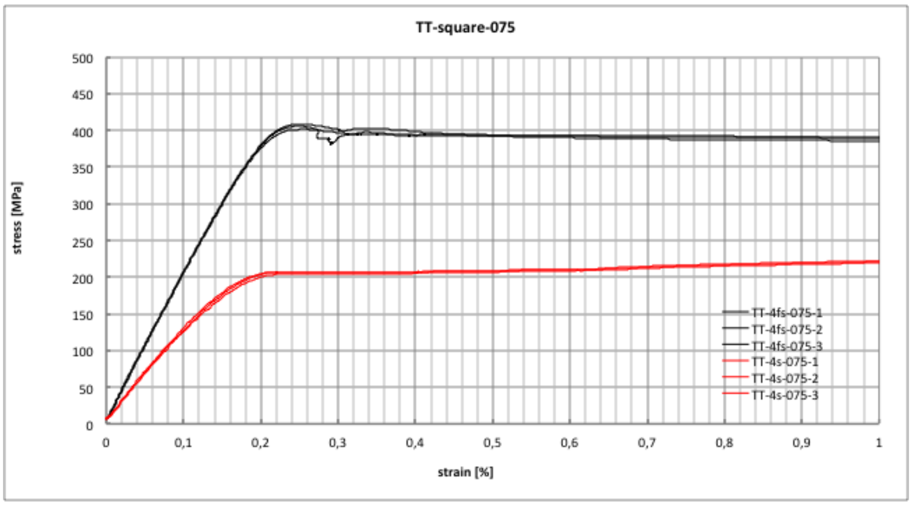


Fig. 2.4.3 – Stress-strain curves without (black curves) and with perforations (red curves) arranged in square for thickness t_N = 0.75 mm

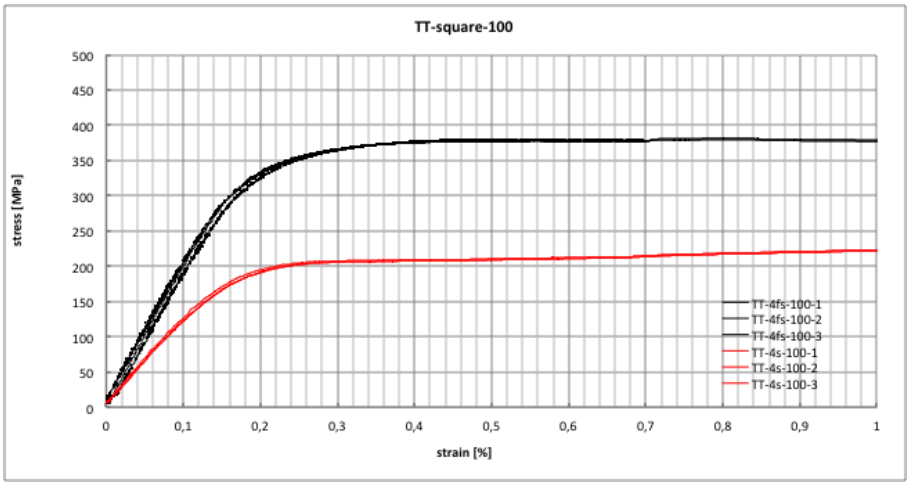


Fig. 2.4.4 – Stress-strain curves without (black curves) and with perforations (red curves) arranged in square for thickness t_N = 1 mm

The stress is decreased by the both perforations, arranged in triangle and in square. The further detailed analysis will allow to determine the ratios between the yield stress of the coupons without perforation and the yield stress of the coupons with perforations.

2.5 Flexion tests

The tests are performed on plates:

a) without perforation
b) with perforation arranged in triangles
c) with perforation arranged in squares

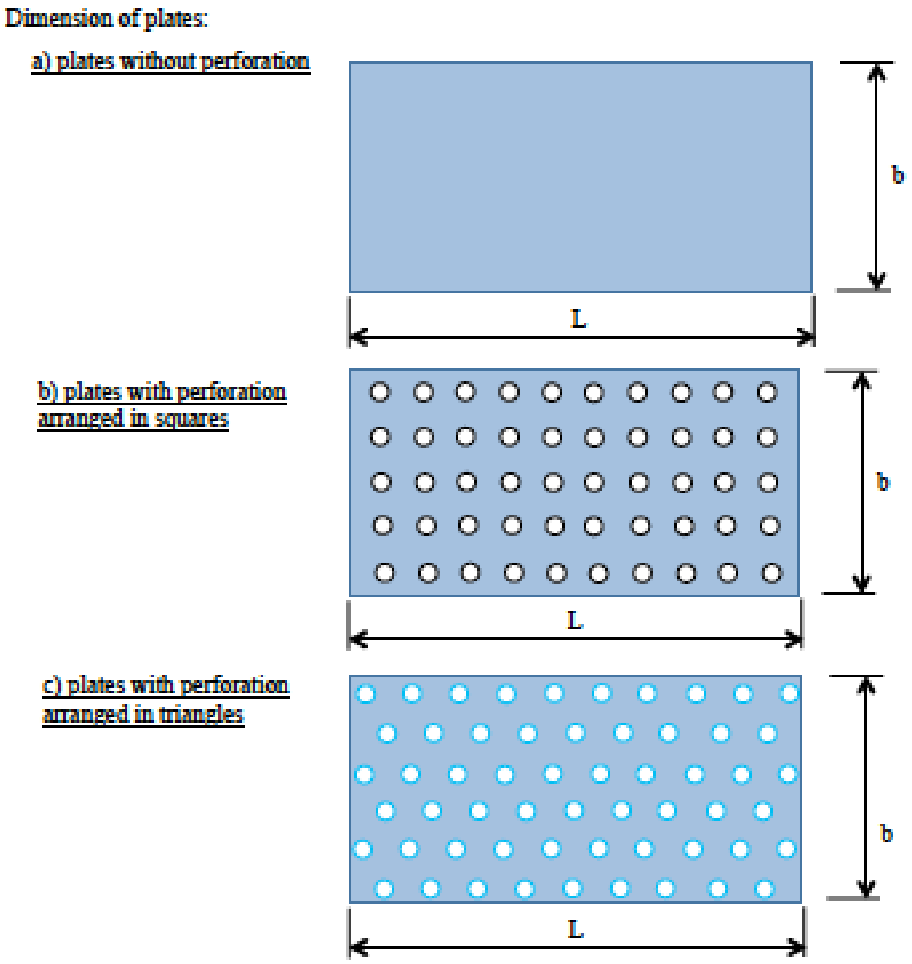
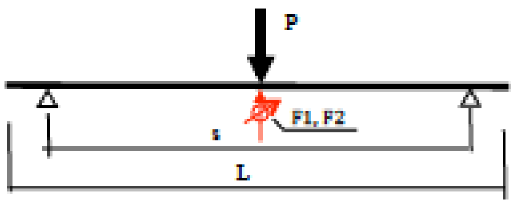


Fig. 3.2.2.1 Dimensions of coupons for plates flexion tests



Figures 2.5.1 and 2.5.2 show all the load-deflection curves without and with perforations arranged in triangle.
Figures 2.5.3 and 2.5.4 show all the load-deflection curves without and with perforations arranged in square.

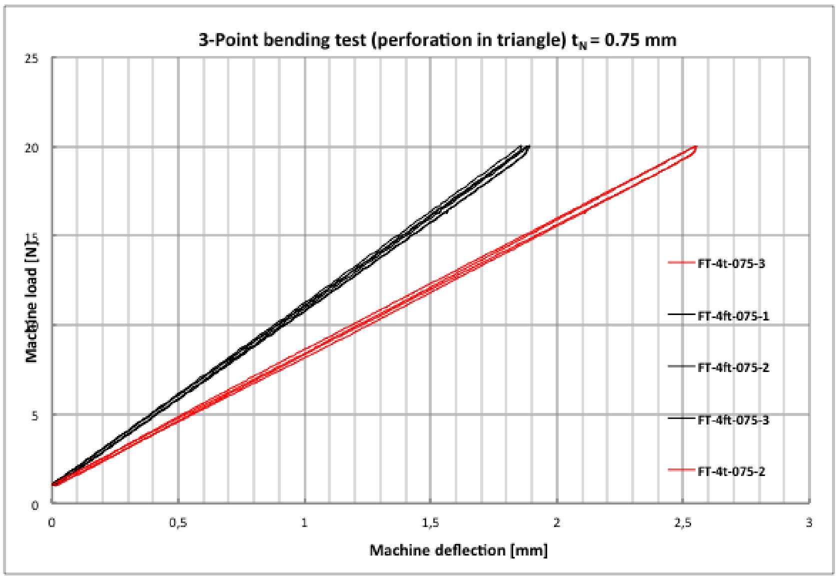


Fig. 2.5.1 – Load-deflection curves without (black curves) and with perforations (red curves) arranged in triangle for thickness t_N = 0,75 mm

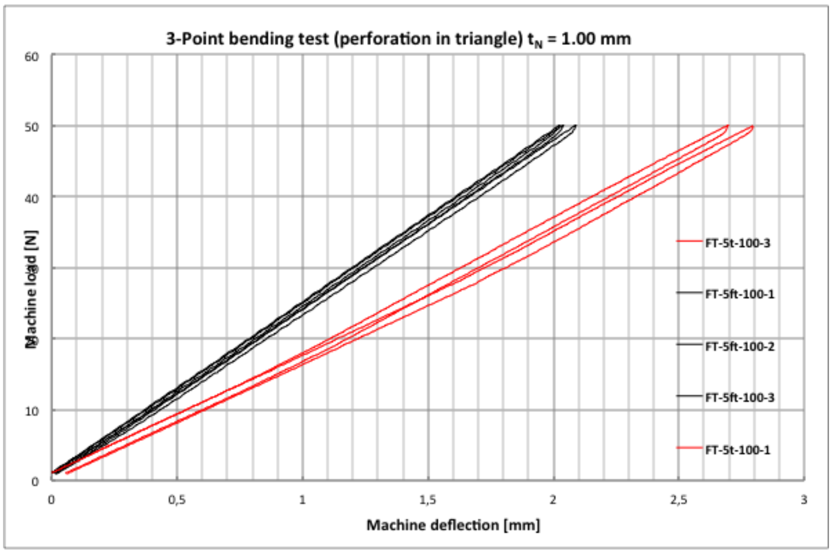


Fig. 2.5.2 – Load-deflection curves without (black curves) and with perforations (red curves) arranged in triangle for thickness t_N = 1 mm

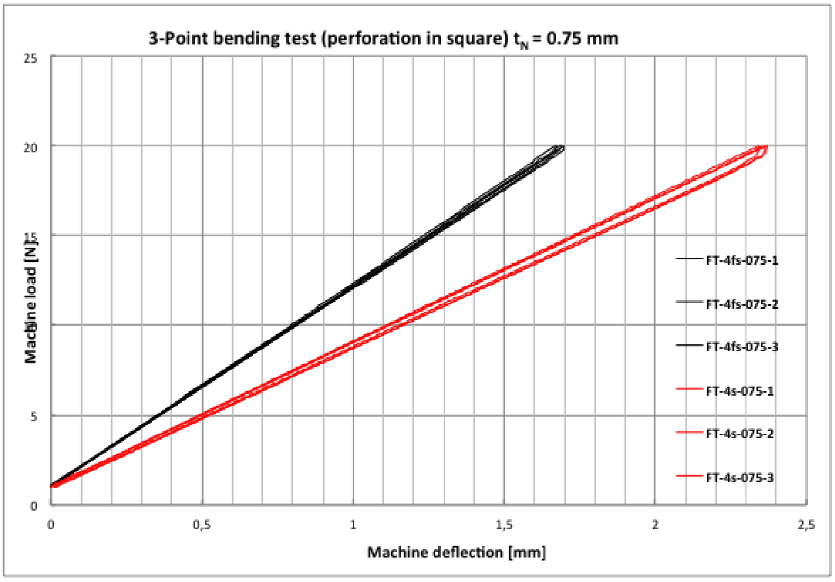


Fig. 2.5.3 – Load-deflection curves without (black curves) and with perforations (red curves) arranged in square for thickness t_N = 0,75 mm

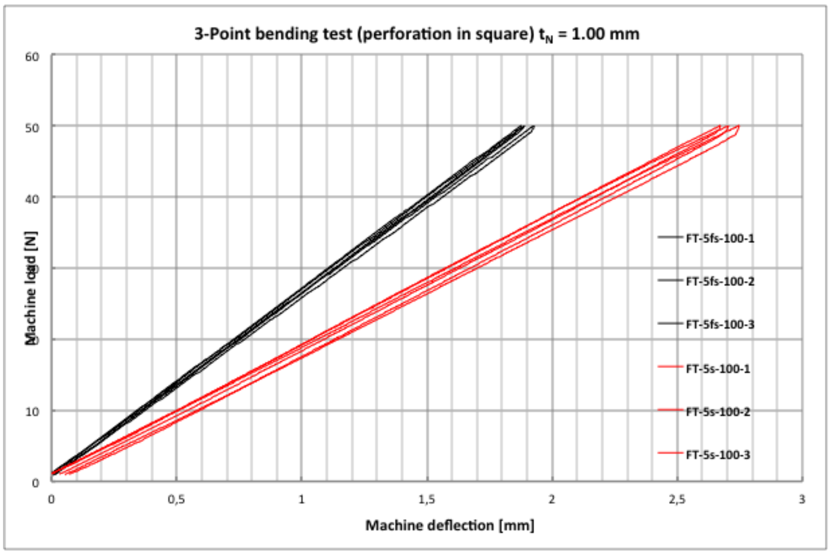


Fig. 2.5.4 – Load-deflection curves without (black curves) and with perforations (red curves) arranged in square for thickness t_N = 0,75 mm

Flexion stiffness are lower for both perforations arranged in square and arranged in triangle. The further detailed analysis will allow to determine the ratios between the flexion stiffness of the coupons without perforation and the yield stress of the coupons with perforations.

3 CONCLUSION

A huge program of 272 tests was performed in order to determine and compare resistance values of profiles without and with perforations (in flange, in web and in both) and with a hole in the upper flange in the middle of the span. It allowed us to conclude:

- The moment resistance:
  - Flange perforation and web perforation induce similar decrease. The resistant moment decreases from 6,2% to 8,6%, and inertia moment decreases from 9,2% to 10,9% for profiles with web or flange perforation. Total perforation (flange + web)

induces much more decrease: from 36,1% to 37,1% for the resistant moment and from 33,3% to 33,6% for the inertia moment.

   - Circular and square holes induce similar decrease. The bigger the hole is, the bigger the decrease of resistant moment is (-12,9% to -15,3% for d=120mm; -5,8 to -10,5%, for d=90mm; -4 to 6,9% for d=105mm). The influence of holes on inertia moment ranges from an increase of 1,2% to a decrease of 9,4%. However, the increasing value is considered as resulting from normal dispersion in the practical conditions and for the safety reason is to be neglected.

- The end support resistance (web crippling):
   - Is slightly decreased by flange perforations (from 1,3% to 4%)
   - Is significantly decreased by web perforations (from 24,4% to 28,7%)
   - Is the most decreased by total perforations (from 34,9% to 38,4%)

- The moment-reaction interaction, in general tendency, is significantly decreased by web perforations (11% to 19%) and total perforations (35% to 42%)

These logical results are comforting the way to further detailed analysis with a view to define the behaviour low of bending and reaction resistance of sections with perforation and with a hole.

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