GRISPE

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

Working Package 2

Test analysis following EN 1993-1-3 for corrugated sheets

30 June 2016

Deliverable D 2.4

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

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D 2.4 test analysis following EN 1993-1-3 for corrugated sheets		***Due date : 30.06.2016*** ***Completion date: 30.06.2016***

1. Introduction

Corrugated steel sheets are the oldest cold formed steel sheets, they have a continuous curvature instead of the flat sections like trapezoidal profiles.

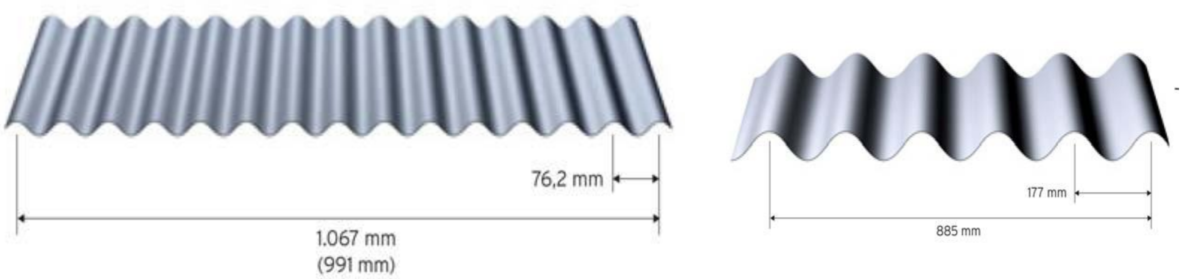

Fig.1: Cross section of the tested profiles

Depending on the R/t-ratio, the failure of these profiles in bending occurs through plastic deformation or through local buckling because of the small slenderness of the compressed part of the profile. The failure under local loads occurs through plastic deformation of the crests or the valleys of the profile.

The aim of the GRISPE project is to develop a design model to calculate the load-bearing capacity in bending and under local loads (end support resistance) and for the combination of bending and support reaction. Therefore three types of tests were executed; single span tests for the positive bending moment (gravity loading) in span, internal support tests for load case gravity loading and uplifting loading with different spans for the moment-support interaction and end support tests for load case gravity loading for the local resistance of the profiles.

In the test report D 2.3 [1] the test range and the results are documented. The tests are evaluated and the ultimate bending moment, the end support resistance and the moment-support interaction were determined in this document D 2.4. A shear test was also done to estimate the level of shear strength in comparison with the compression test resistant (end support test)

2. Description of the tested profiles

2.1 Cross sections

Two different profiles in two thicknesses (different R/t-ratio) were tested. They are shown in Figures 2 and 3.

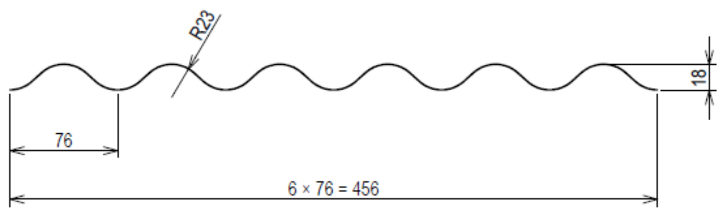

Fig. 2: Cross section of the profile 18/76

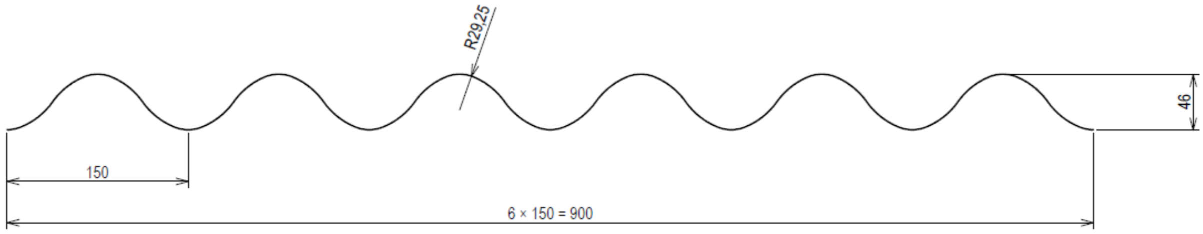

Fig. 3: Cross section of the profile 46/150

The geometry of the used profiles was measured at 3 different specimens per batch. The results are given in [1]. The measured values are sufficiently close to the nominal values. The used specimen and the test results can be considered as representative for the nominal cross sections.

2.2 Material

The tested profiles were produced from coils steel grade S320 GD according to EN 10346. From different test specimen material samples were taken and tensile tests executed. The results are given in table 1.

profile/batch	material	nominal values	test no.	measured values			
		t_N (mm) f_{yb} (N/mm²) f_u (N/mm²)		$t_{cor,obs}$ mm	$f_{yb,obs}$ N/mm²	$f_{u,obs}$ N/mm²	$A_{L=80}$ %
Bacacier 18/76 - 0,63 mm	steel S320 GD	0,63	1	0,50	339	469	24,6
		320	2	0,55	340	462	25,3
		390	3	0,52	322	450	24,8
			mean values	0,523	333,7	460,3	24,9
Bacacier 18/76 - 1,00 mm	steel S320 GD	1,00	1	0,93	404	458	20,9
		320	2	0,96	412	457	21,7
		390	3	0,94	390	453	22,0
			mean values	0,943	402,0	456,0	21,5
Bacacier 46/150 - 0,63 mm	steel S320 GD	0,63	1	0,51	361	409	28,5
		320	2	0,53	362	410	28,9
		390	3	0,52	370	409	27,4
			mean values	0,520	364,3	409,3	28,3
Bacacier 46/150 - 1,00 mm	steel S320 GD	1,00	1	0,92	413	462	21,2
		320	2	0,95	422	465	21,7
		390	3	0,93	392	457	21,8
			mean values	0,933	409,0	461,3	21,6

Table 1: Observed material properties and reference values

The scattering of the individual values among the samples of the same batch is very small; the mean values of the batch can be considered as representative for all test specimen of the same batch.

3. Principles of test evaluation

3.1 Adjustment of test results

Considering the aim of the tests, the test results are not adjusted to nominal material properties (yield stress, core thickness). When the design approach is compared with the test values, the design values are calculated with the properties of the test specimen, i.e. mean values of core thickness and yield stress or the test samples of the same batch.

3.2 Characteristic values

The characteristic values of the searched bearing properties are determined by a statistical evaluation of the test results.

A test series in this context includes all tests with the same test setup and the same failure mode. In detail, all single span tests perform one family (15 tests), all internal support tests downward loading for 1 profile (2 x 16 tests), all internal support tests uplift loading for 1 type of fixing (2 x 16 tests) and all end support tests (14 tests). A test family consists of several subsets; a subset contains 2 or 3 identical tests for the same profile, same thickness, same span, same loading and so on.

The test results of a subset are referred to its specific mean value Rm; the statistical evaluation is done with these normalized values.

The characteristic value is :

$R_k = R_m \cdot (1 - k \cdot s)$

R_m mean value of the subset

s standard deviation

k coefficient depending of the number of tests according to table 2

n	3	4	5	6	8	10	20	30	∞
k	-	2,63	2,33	2,18	2,00	1,92	1,76	1,73	1,64

Table 2: fractile coefficients k according to EN 1993-1.3 table A.2

4. Test analysis
4.1 Overview of the tests done

The tests done were the following:

<table>
<tr><th rowspan="2">Type of test</th><th rowspan="2">Thickness [mm]</th><th rowspan="2">Support width [mm] / Fastening</th><th colspan="2">Span [mm]</th><th colspan="2">Number of tests</th></tr>
<tr><th>18/76</th><th>46/150</th><th>18/76</th><th>46/150</th></tr>
<tr><td rowspan="2">Single span test with gravity loading</td><td>0.63</td><td>-</td><td>1500</td><td>2000</td><td>3</td><td>6</td></tr>
<tr><td>1.00</td><td>-</td><td>2000</td><td>3000</td><td>3</td><td>3</td></tr>
<tr><td rowspan="8">Internal support tests with gravity loading</td><td rowspan="4">0.63</td><td rowspan="2">10</td><td>400</td><td>600</td><td>2</td><td>2</td></tr>
<tr><td>800</td><td>1000</td><td>2</td><td>2</td></tr>
<tr><td rowspan="2">40</td><td>400</td><td>600</td><td>2</td><td>2</td></tr>
<tr><td>800</td><td>1000</td><td>2</td><td>2</td></tr>
<tr><td rowspan="4">1.00</td><td rowspan="2">10</td><td>400</td><td>600</td><td>2</td><td>2</td></tr>
<tr><td>1000</td><td>1200</td><td>2</td><td>2</td></tr>
<tr><td rowspan="2">40</td><td>400</td><td>600</td><td>2</td><td>2</td></tr>
<tr><td>1000</td><td>1200</td><td>2</td><td>2</td></tr>
<tr><td rowspan="8">Internal support tests with uplift loading</td><td rowspan="4">0.63</td><td rowspan="2">valley</td><td>400</td><td>600</td><td>2</td><td>2</td></tr>
<tr><td>800</td><td>1000</td><td>2</td><td>2</td></tr>
<tr><td rowspan="2">crest</td><td>400</td><td>600</td><td>2</td><td>2</td></tr>
<tr><td>800</td><td>1000</td><td>2</td><td>2</td></tr>
<tr><td rowspan="4">1.00</td><td rowspan="2">valley</td><td>400</td><td>900</td><td>2</td><td>2</td></tr>
<tr><td>1000</td><td>1400</td><td>2</td><td>2</td></tr>
<tr><td rowspan="2">crest</td><td>400</td><td>900</td><td>2</td><td>2</td></tr>
<tr><td>1000</td><td>1400</td><td>2</td><td>2</td></tr>
<tr><td rowspan="2">End support tests with gravity loading</td><td>0.63</td><td>-</td><td>1000</td><td>1050</td><td>4</td><td>3</td></tr>
<tr><td>1.00</td><td>-</td><td>1000</td><td>1050</td><td>4</td><td>3</td></tr>
<tr><td>Shear test</td><td>0.63</td><td>-</td><td>1000</td><td>1000</td><td>1</td><td>1</td></tr>
</table>

Table 3: Tests done for corrugated profiles, test parameters

4.2 Self weight of the test specimens

The self-weight of the test specimens is taken from the producer's brochure.

profile	thickness t (mm)	self-weight (kN/m²)
Bacacier 18/76	0,63	0,063
	1,00	0,099
Bacacier 46/150	0,63	0,067
	1,00	0,106

Table 4: self-weight of the tested profiles

4.3 Single span tests, bending moment capacity of the corrugated profiles Corrugated

The tests are executed conform to the EN 1993-1-3 and are defined in the drawing below. The load is applied as 4 line loads at 0,125 L – 0,25 L – 0,25 L – 0,25 L – 0,125 L. Due to the isostatic load distribution system, all 4 line loads are equal.

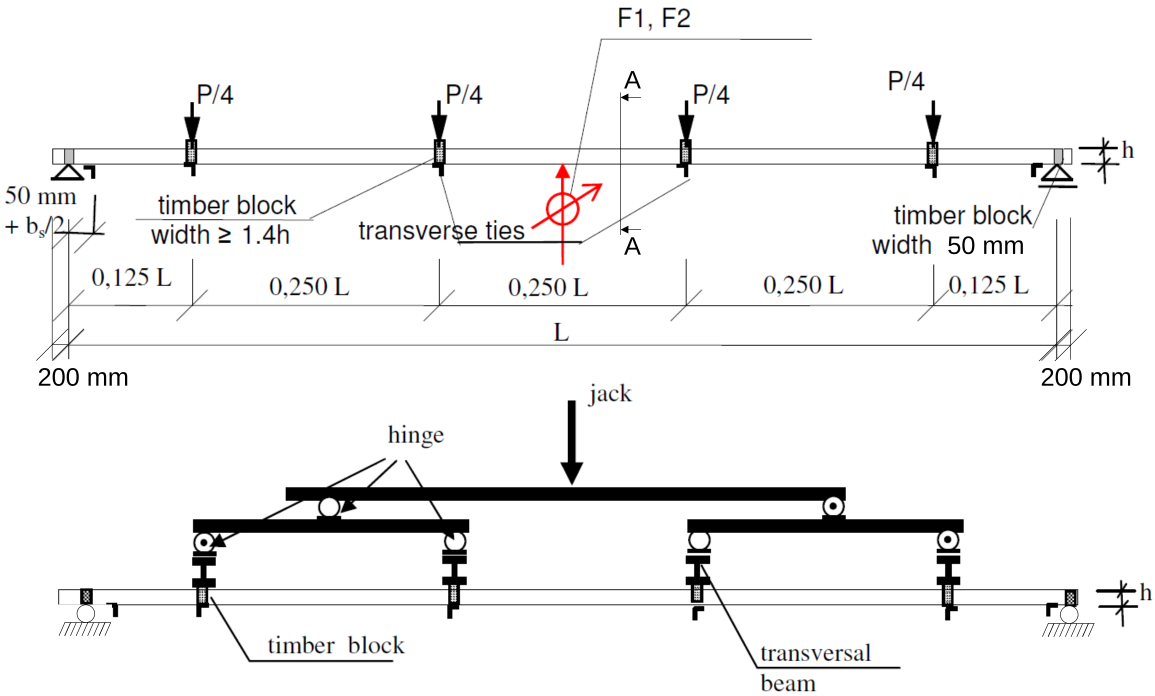

Fig. 4: Test setup single span tests

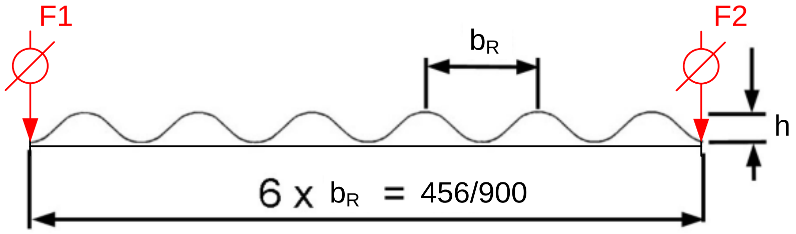

Fig. 5: Cross section of the test specimen (in mid-span)

Maximum bending moment in span:

$$M_{c,Rk,F} = F_{u,k} / b_V * L/8 + g * L_V * [\, 2\, L - L_V] / 8$$

$M_{c,Rk,F}$ characteristic bending moment in span (kNm/m)

$F_{u,k}$ characteristic load in kN (including preload)

b_V width of the test specimen (here: b_V = 0,456 or 0,90 m)

L_V length of the test specimen (here: L_V = 1,90 or 2,40 or 3,40 m)

L span length (here: L = 1,50 or 2,00 or 3,00 m)

g self-weight of the test specimen according to table 4

The detailed test evaluation is presented in the annex page 1.

Two modes of failure occurred:

- Yielding
- Buckling of the compressed part

Fig. 6: Example of tests done on corrugated profiles -18x76 t =1mm

Fig. 7: Example of tests done on corrugated profiles 18x76 t = 0.63 mm – failure by buckling

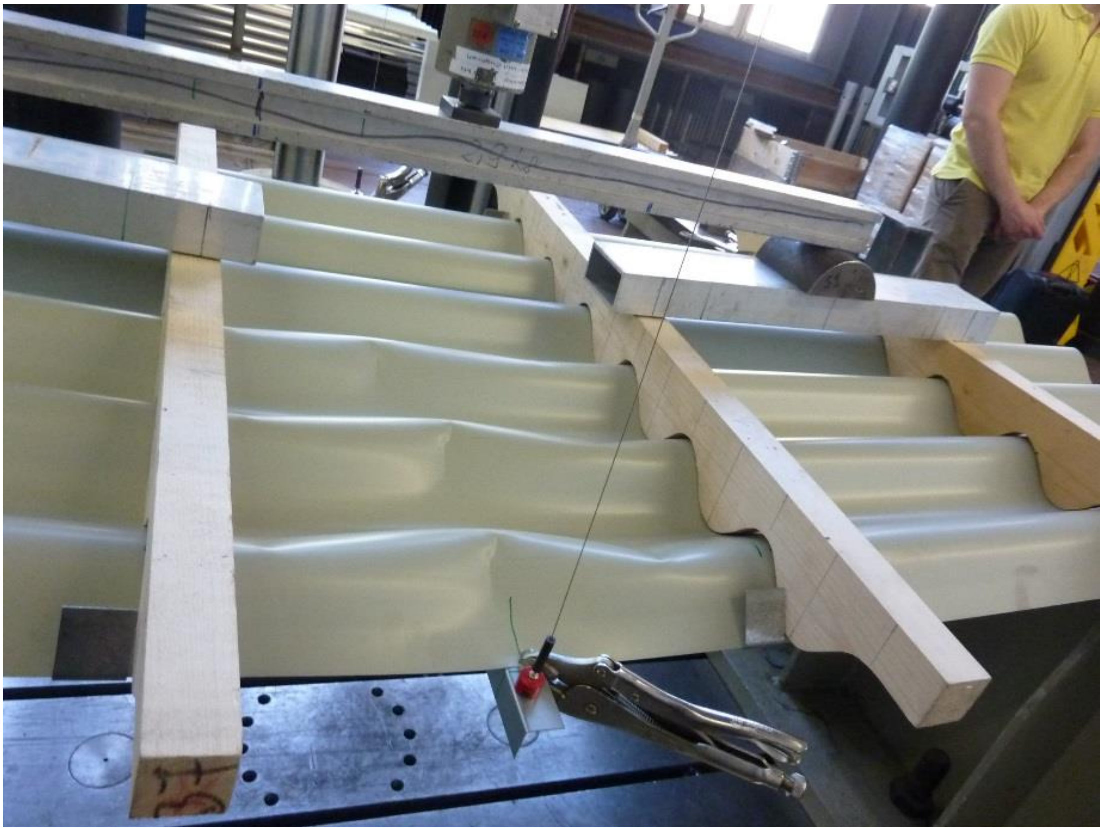

Fig. 8: Example of tests done on corrugated profiles 46x150 t = 0.63 mm – failure by buckling

Fig. 9: Example of tests done on corrugated profiles 46x 150 t = 1 mm - failure by buckling

Fig. 10: Example of tests done on corrugated profiles 18x 76 t = 1 mm – yielding

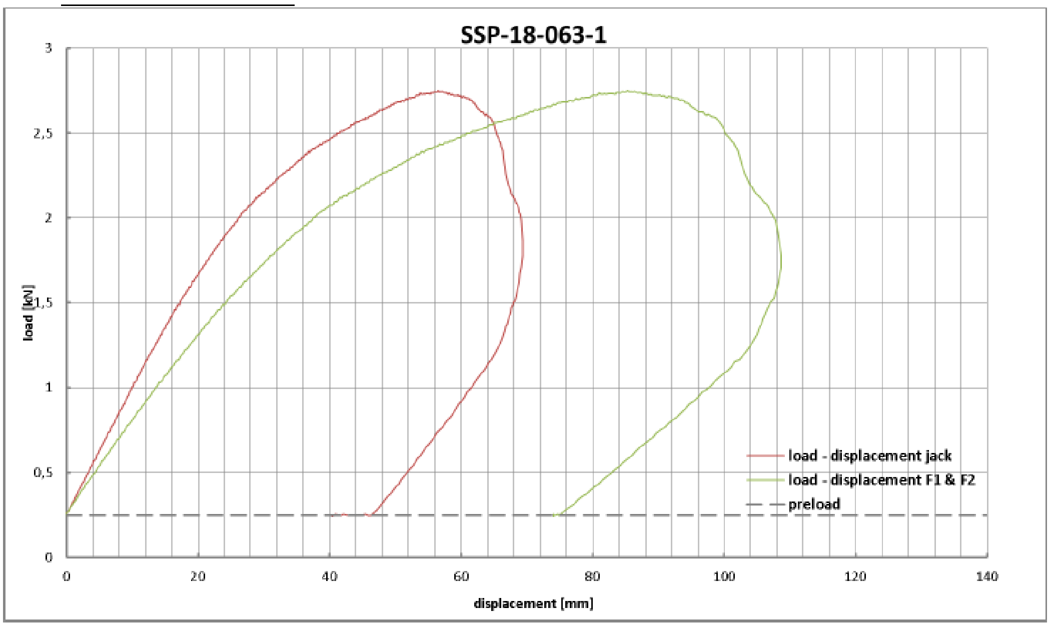

Fig. 11: Test results on 18x76 nominal thickness 0.63 mm

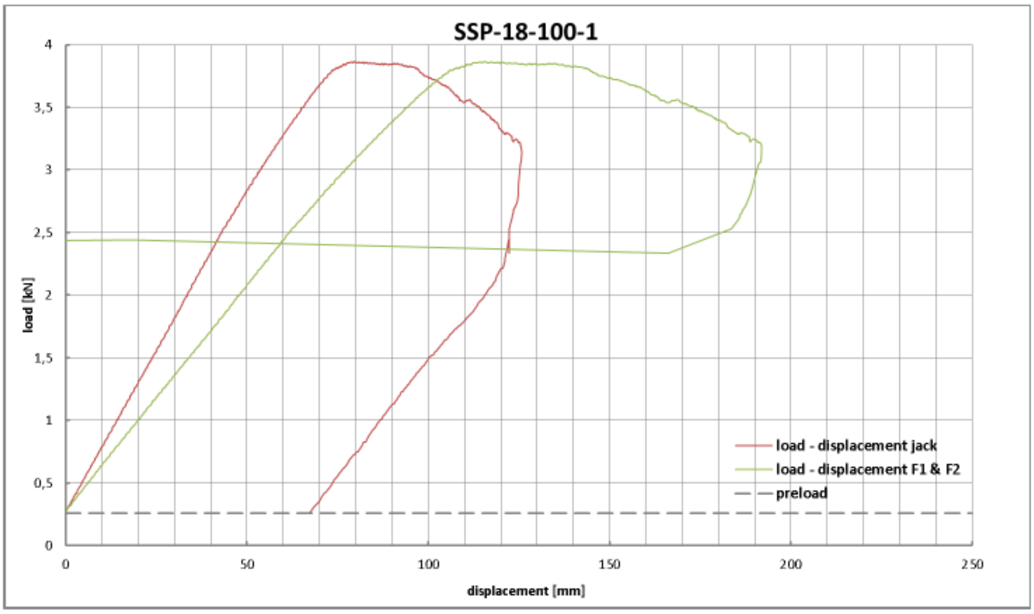

Fig. 12: Test results on 18x76 nominal thickness 1.0 mm

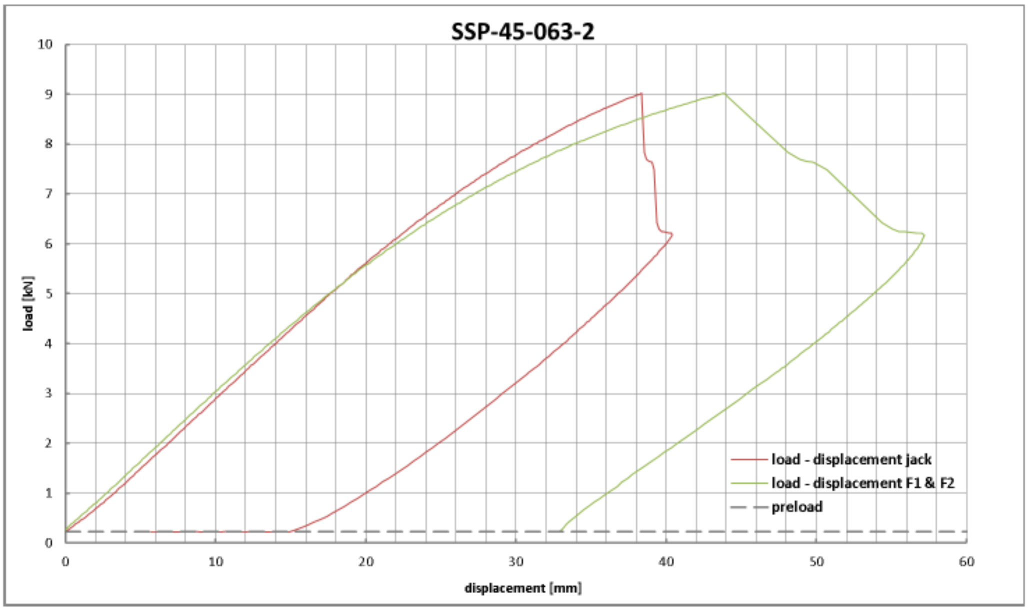

Fig. 13: Test results on 46x150 nominal thickness 0.63 mm

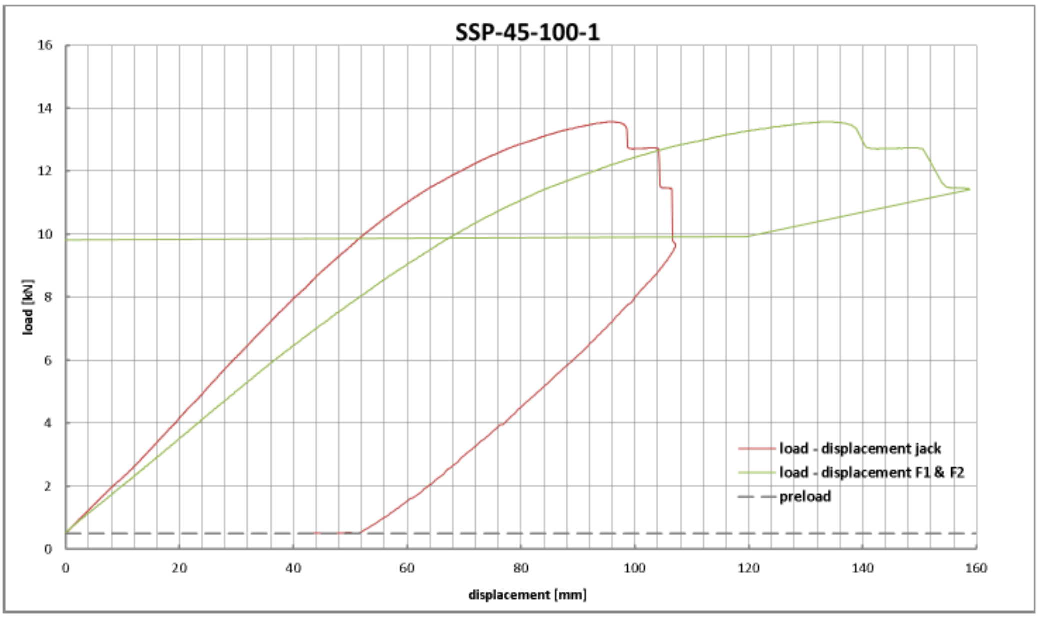

Fig. 14: Test results on 46x150 nominal thickness 1.00 mm

Profile	nominal thickness t mm	steel core thickness t_{cor} mm	yield strength f_{yb} N/mm²	span moment $M_{c,Rk,F}$ kNm/m
Bacacier 18/76	0,63 1,00	0,523 0,943	333,7 402,0	1,09 2,08
Bacacier 46/150	0,63 1,00	0,520 0,933	364,3 409,0	2,41 5,47

Table 5: Test results: characteristic bending moment in span

4.4 Intermediate support tests for downward loading

The tests are executed conform to the EN 1993-1-3 and are defined in the drawing below. The load, which represents in the real situation the support reaction, is applied as a line load in mid-span. The width of the load traverse, which corresponds to the width of the support, is chosen to 10 mm and 40 mm.

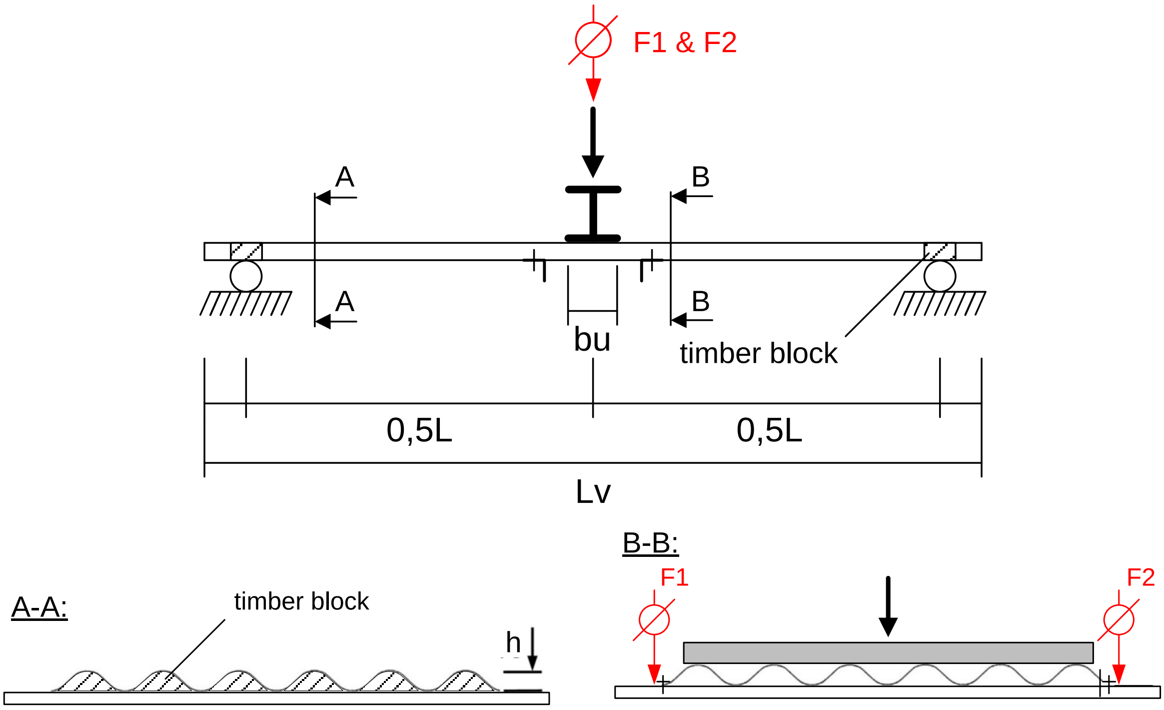

Fig. 15: Test setup intermediate support tests for downward loading

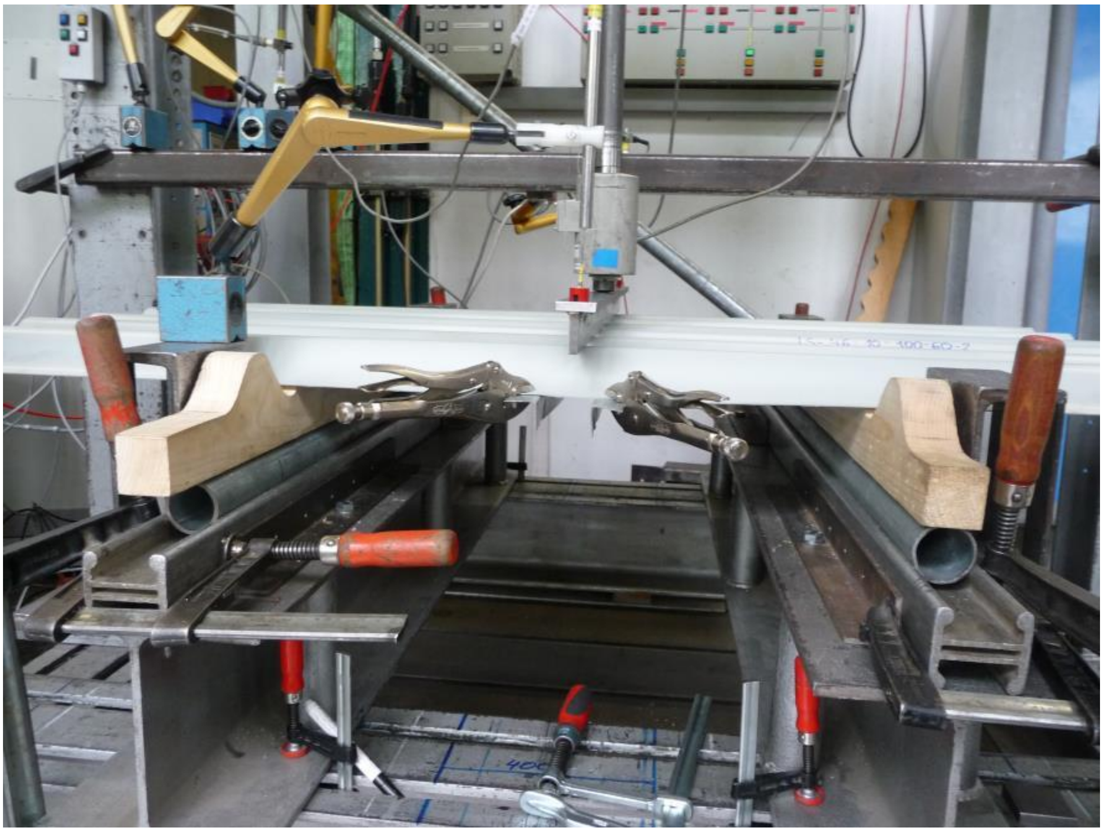

Fig. 16: Test setup (exemplary for bu = 10mm)

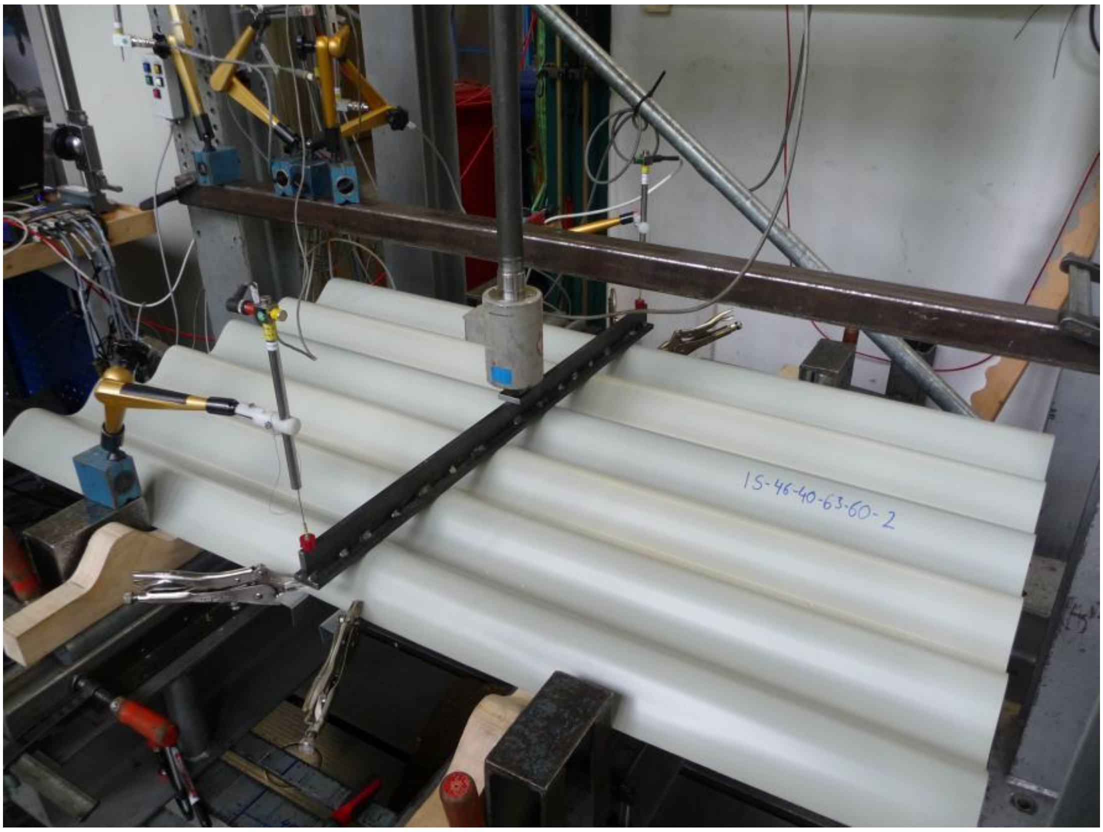

Fig. 17: Test setup (exemplary for bu = 40mm)

The characteristic support reaction and the characteristic bending moment are determined with the following formulas:

- Support reaction:

$$R_{w,Rk,B} = F_{u,k} / b_V$$

- Bending moment at support

$$M_{c,Rk,B} = R_{w,Rk,B} * L/4 + g * L_V * [2 L – L_V] / 8$$

$R_{w,Rk,B}$	characteristic support reaction at intermediate support (kN/m)
$M_{c,Rk,B}$	characteristic bending moment at intermediate support (kNm/m)
$F_{u,k}$	characteristic load in kN (including preload)
b_V	width of the test specimen
L_V	length of the test specimen
L	span length
g	self-weight of the test specimen according to table 4

The following photos show the failure of the test specimens which is dominated by local deformations and buckling of the compressed parts of the cross section.

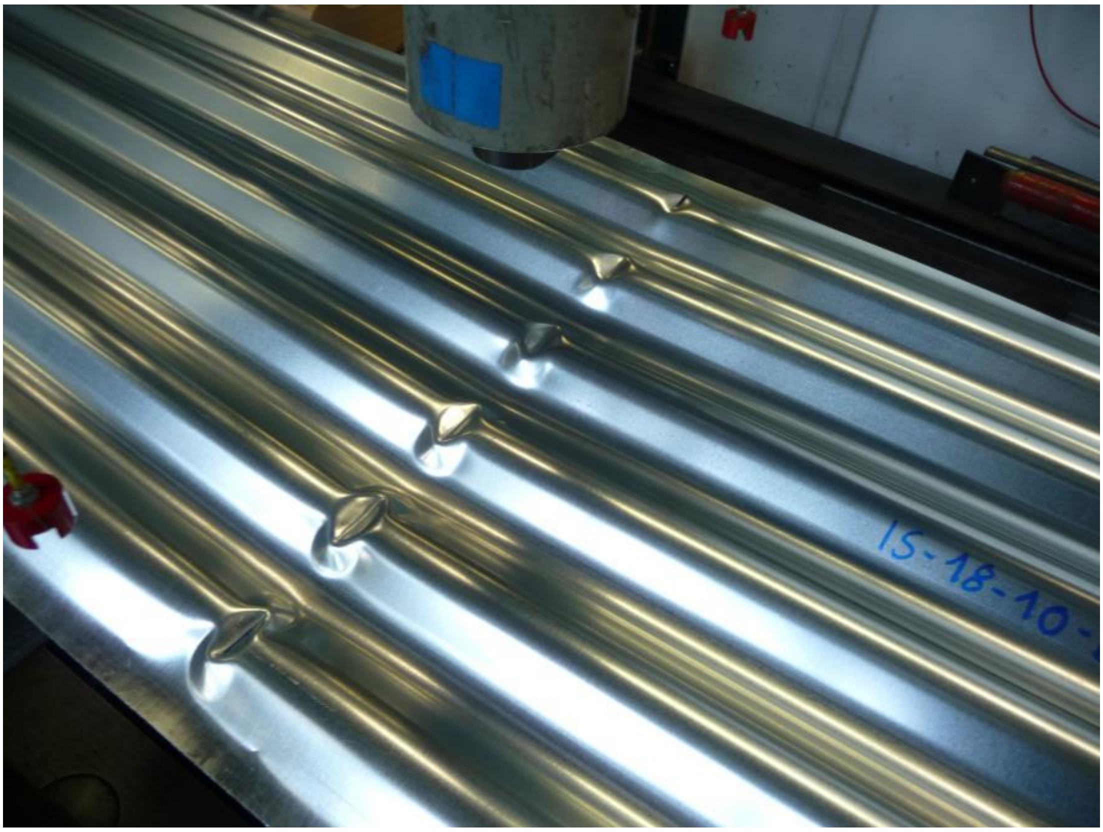

Fig. 18: Failure mode (exemplary IS-18-10-63-80-1)

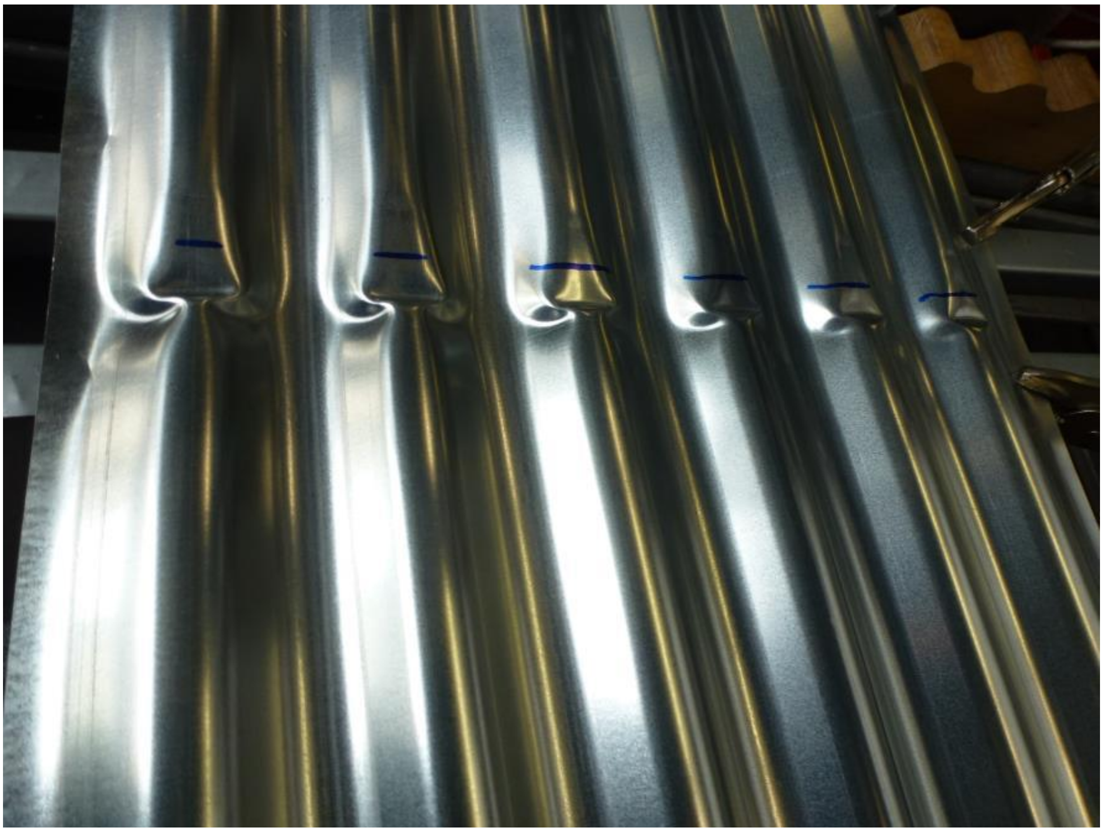

Fig. 19: Failure mode (exemplary IS-18-40-63-40-2)

Fig. 20: Failure mode (exemplary IS-46-10-100-60-2)

Fig. 21: Failure mode (exemplary IS-46-40-100-60-2)

The detailed test evaluation for downward loading is presented in the annex page 2 – 5 and page 10 - 13. Table 6 gives the final results of these tests.

Profile	nominal thickness t mm	support width $L_{a,B}$ mm	maximum bending moment $M_{c,Rk,B}$ kNm/m	corresp. support reaction R_1 kN/m	corresp. bending moment M_2 kNm/m	max. support reaction $R_{w,Rk,B}$ kN/m	interaction parameter $M^0_{Rk,B}$ kNm/m	interaction parameter $R^0_{Rk,B}$ kN/m
Bacacier 18/76	0,63	10	0,88	4,40	0,77	7,81	1,02	32,00
		40	1,12	5,61	1,05	10,58	1,21	81,80
	1,00	10	2,27	9,06	2,01	20,15	2,49	104,44
		40	2,44	9,75	2,58	25,88	2,44	∞
Bacacier 46/150	0,63	10	1,20	4,79	0,98	6,55	1,81	14,26
		40	1,27	5,07	1,09	7,31	1,68	20,83
	1,00	10	3,74	12,43	3,02	20,12	4,92	52,04
		40	3,92	13,03	3,36	22,40	4,71	78,14

Table 6: Characteristic M/R-combinations and definition of the interaction diagrams

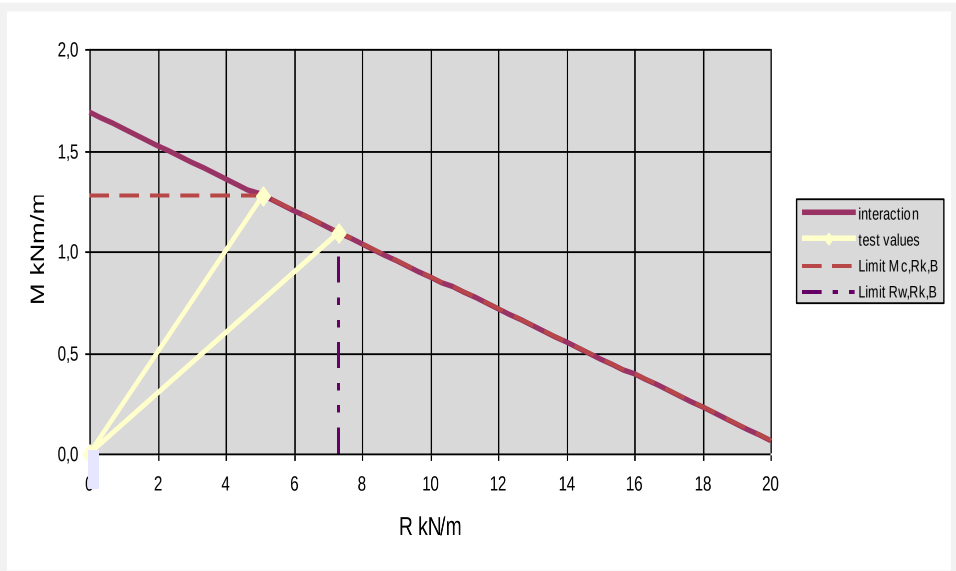

Fig. 22: Example of an interaction diagram M/R at intermediate supports

4.5 Intermediate support tests for uplift loading

The tests are executed conform to the EN 1993-1-3 and are defined in the drawing below. The load, which represents in the real situation the support reaction, is applied via the fixing elements as a row of punctual loads in mid-span. Both fixing configurations “fixing on the crest of the waves” and “fixing in the valleys” were investigated.

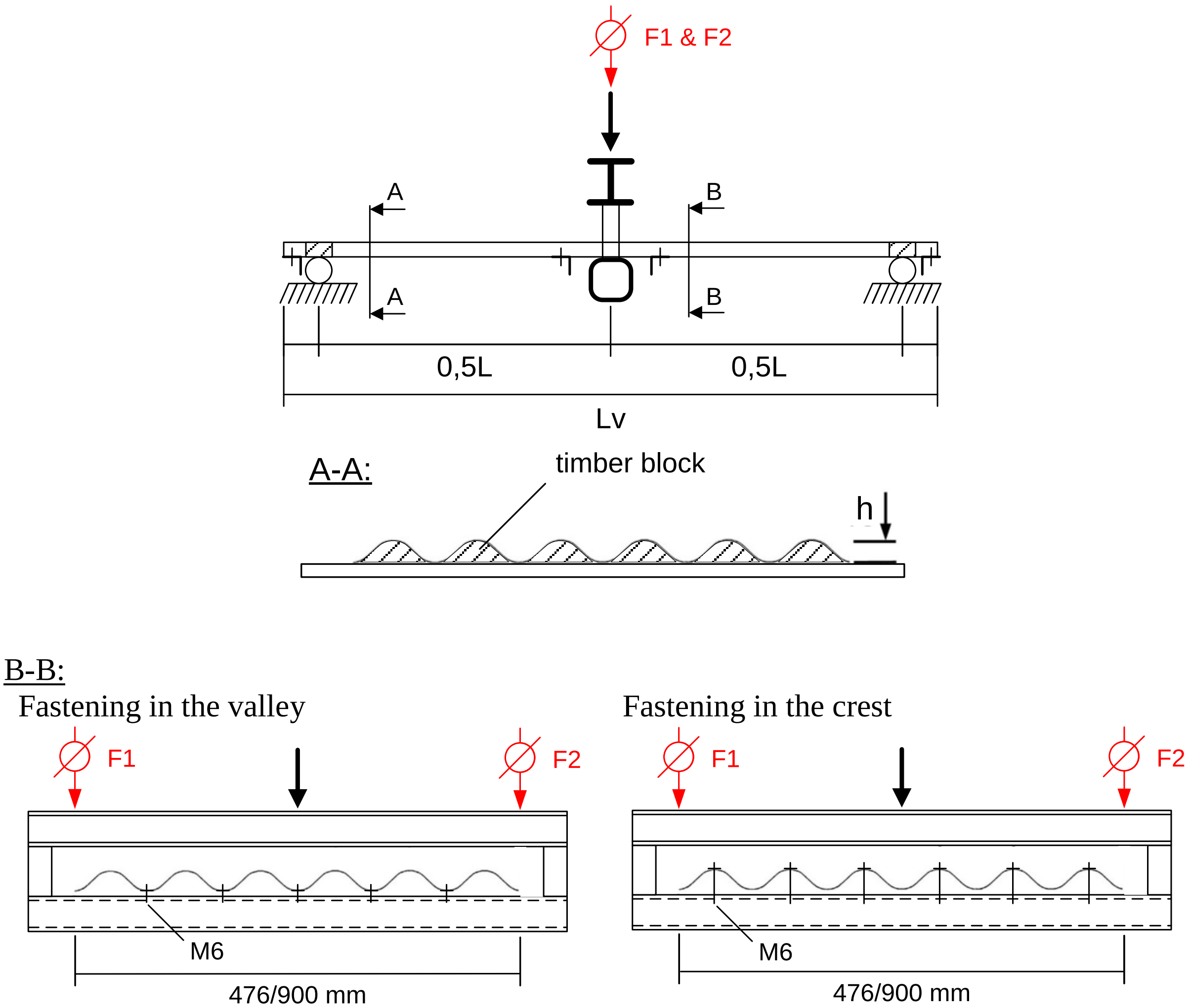

Fig. 23: Test setup intermediate support tests for uplift loading

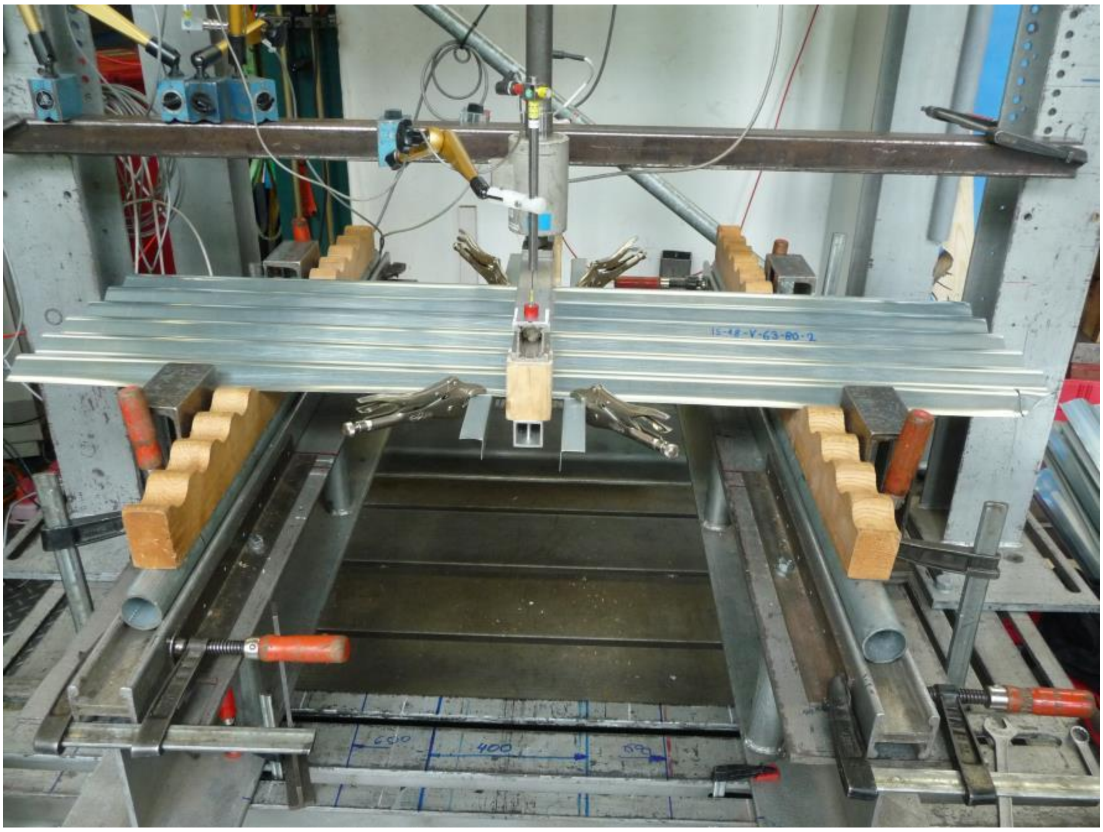

Fig. 24: Test setup (front view)

Fig. 25: Test setup (exemplary for fastening in the valley of the sheet)

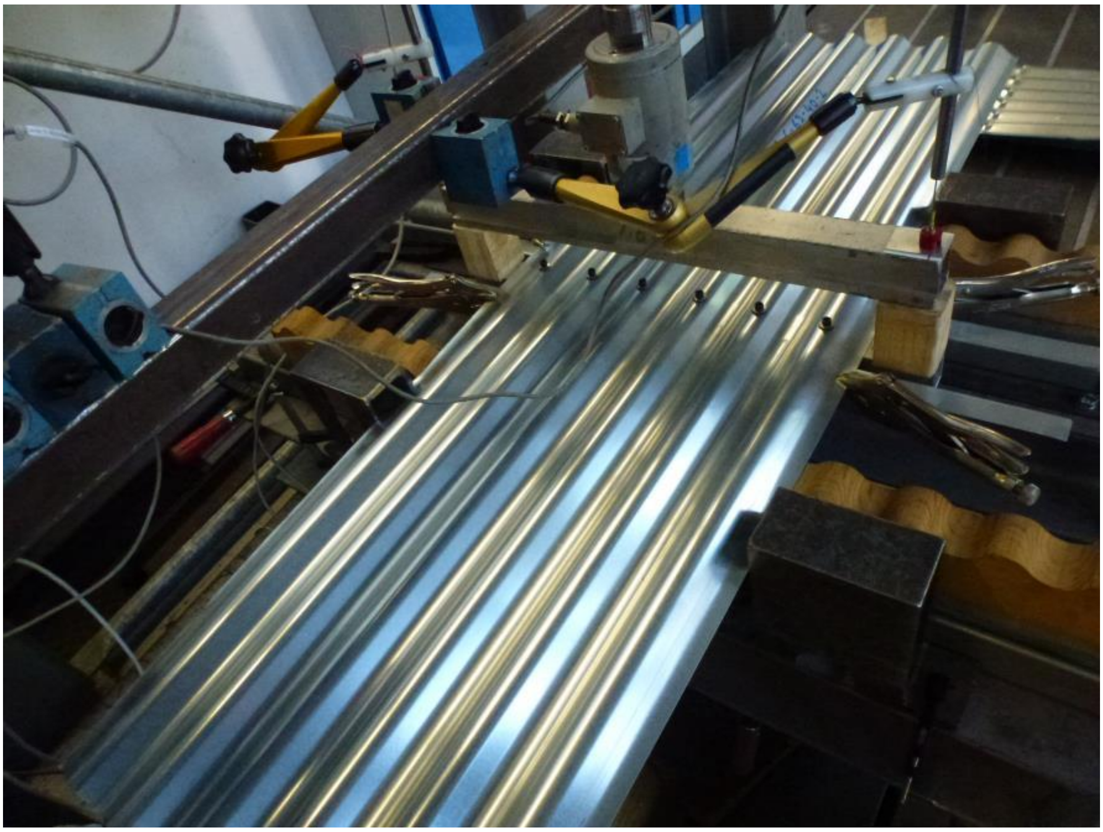

Fig. 26: Test setup (exemplary for fastening in the crest of the sheet)

The characteristic support reaction and the characteristic bending moment for uplift loading are determined with the same formulas as for downward loading (see chapter 4.4)

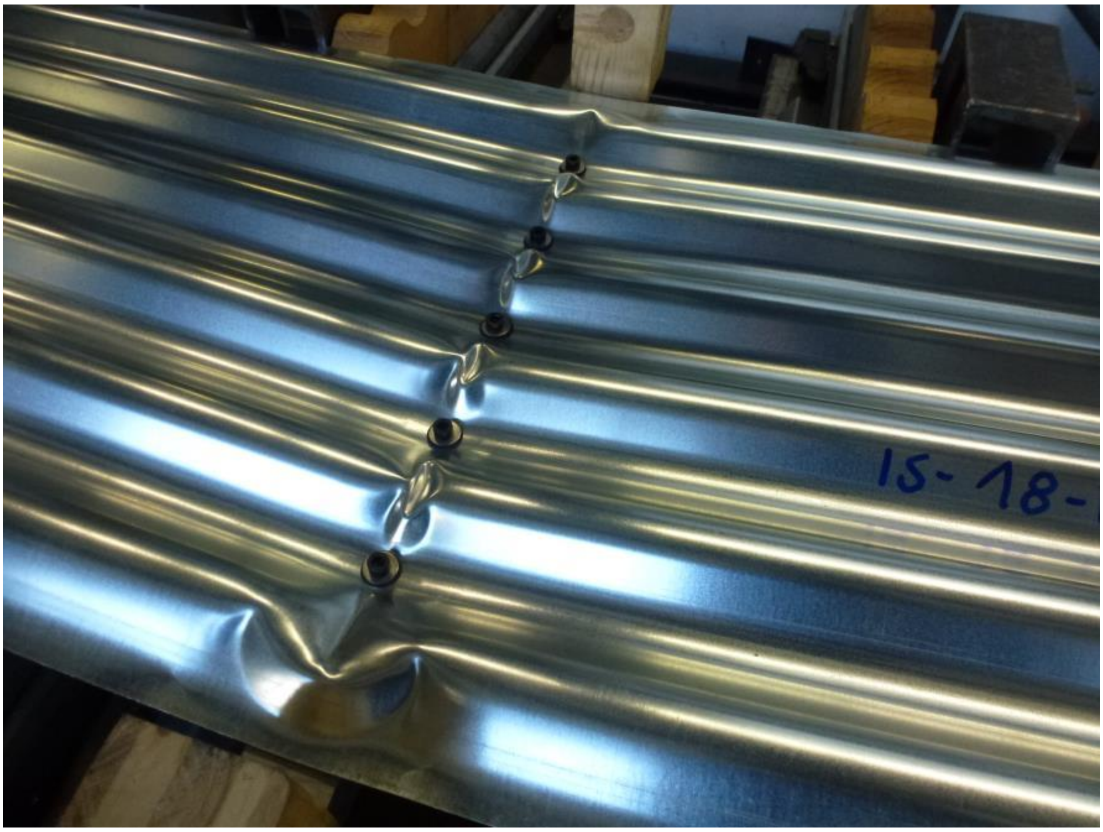

Fig. 27: Failure mode (exemplary IS-18-V-63-40-1)

Fig. 28: Failure mode (exemplary IS-18-C-63-40-1a)

Fig. 29: Failure mode (exemplary IS-46-V-100-90-1)

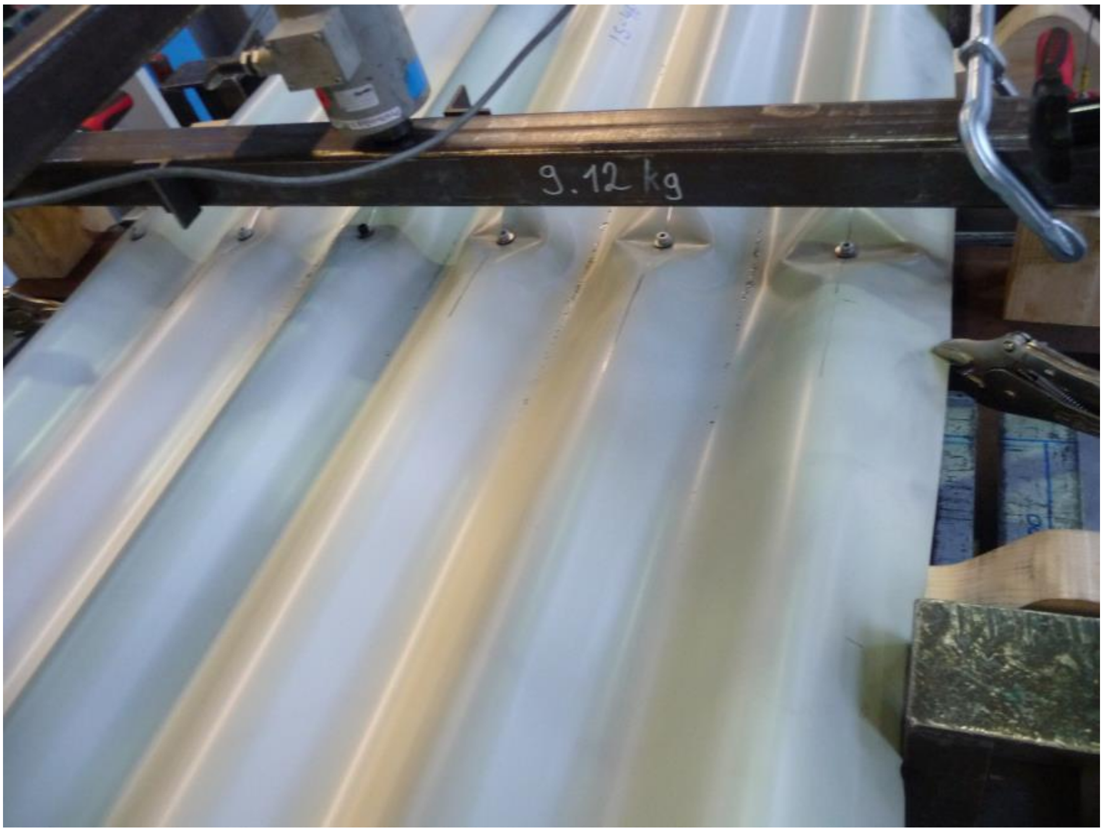

Fig. 30: Failure mode (exemplary IS-46-C-63-60-1)

The detailed test evaluation for downward loading is presented in the annex page 6 – 9 and page 14 - 17. Table 7 gives the final results of these tests.

Profile	nominal thickness t mm	fixing config-uration	maximum bending moment $M_{c,Rk,B}$ kNm/m	corresp. support reaction R_1 kN/m	corresp. bending moment M_2 kNm/m	max. support reaction $R_{w,Rk,B}$ kN/m	interaction parameter $M^0_{Rk,B}$ kNm/m	interaction parameter $R^0_{Rk,B}$ kN/m
Bacacier 18/76	0,63	crest	0,85	4,23	0,74	7,52	0,98	31,22
		valley	1,06	5,31	1,13	11,41	1,06	∞
	1,00	crest	2,13	8,50	1,87	18,83	2,34	94,17
		valley	2,26	9,02	2,33	23,40	2,26	∞
Bacacier 46/150	0,63	crest	0,99	3,95	0,84	5,64	1,34	15,16
		valley	2,36	9,43	2,34	15,62	2,36	∞
	1,00	crest	3,59	10,22	3,08	13,67	5,11	34,39
		valley	5,62	16,01	5,44	24,16	5,62	∞

Table 7: Charcteristic M/R combinations and definition of the interaction diagrams

In the case of fixing on the crest of the waves, failure occurred by a combination of local deformations under the heads of the screws and of local buckling of the compressed parts of the cross section (see fig. 28 and 30). The interaction diagram shows a considerable influence of the support reaction R on the bending moment.

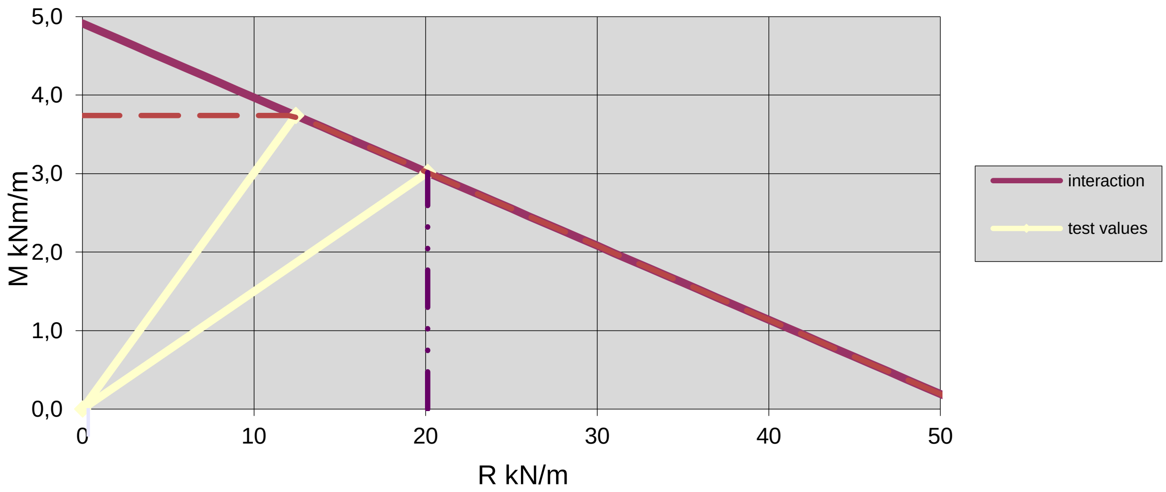

Fig. 31: Typical M/R-interaction for uplift loading and fixing on crest

When the profile is fixed in the valleys, local buckling of the compressed parts of the cross section leads to failure and determines the ultimate bending moment. There is no local compression of the cross section (see fig. 27 and 29) as it can be stated with fixing on the crest. The interaction M/R is more or less horizontal; this means, that the bending moment capacity is not reduced with increasing support reaction.

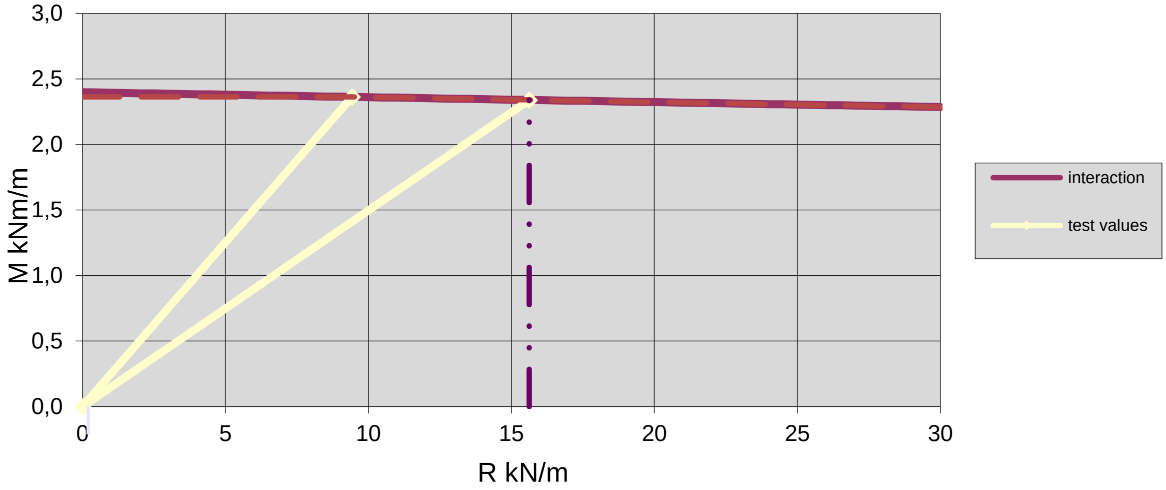

Fig. 32: Typical M/R-interaction for uplift loading and fixing in the valley

4.6 Comparison of the bearing capacity at internal supports for downward and for uplift loading

At intermediate supports, bending moment and support reaction are acting simultaneously, and failure occurs by a combined solicitation. Bending moments leads to local buckling in the compressed area of the cross section and/or to yielding of the material. The support reaction creates local deformations of the cross section and shear stresses. Especially the local deformations reduce more or less the bending moment capacity.

In the following diagrams, the combined load bearing capacity M-R is shown for every profile and every tested thickness. As a reference value, the characteristic bending moment in span (= bending moment capacity without any reduction due to local deformations) is marked with the horizontal orange line.

The M/R-interaction for downward loading are marked with the red line (support width 10 mm) or with the blue line (support width 40 mm); the M/R-interaction for uplift loading are marked with the green line (fixing on every crest) or with the black line (fixing in every valley).

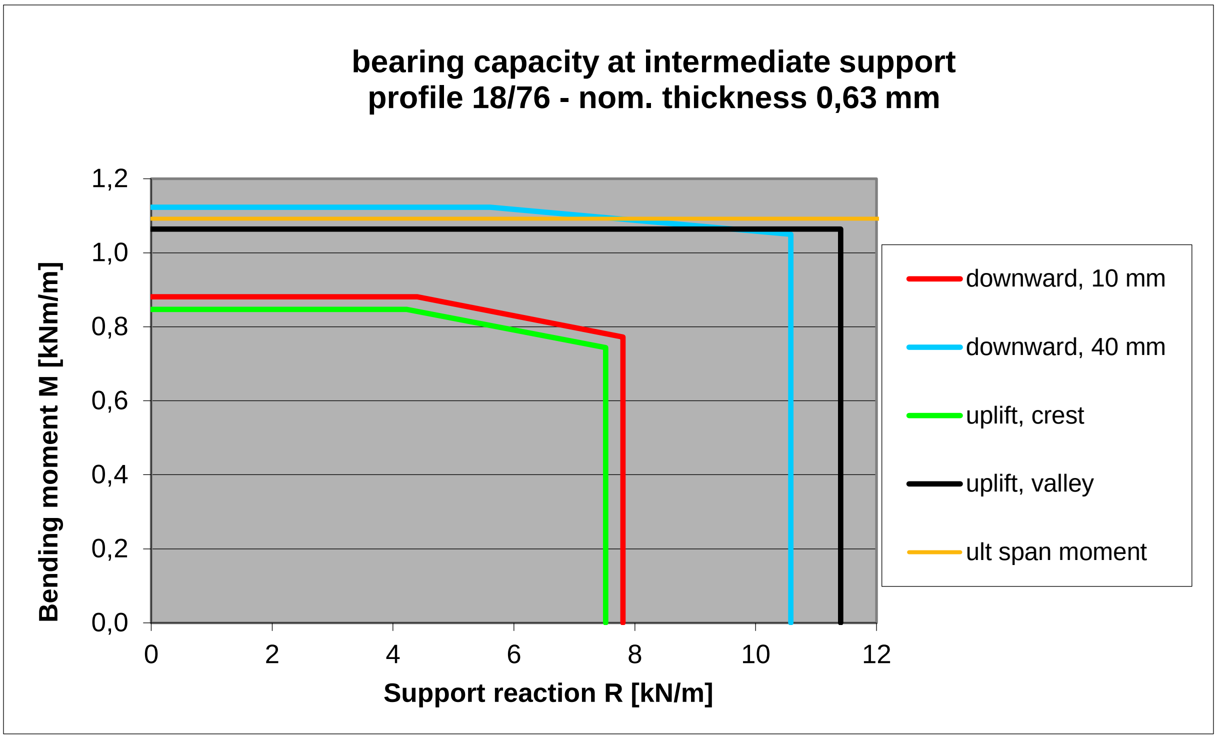

Fig. 33: Comparison M/R-interaction for different support conditions, profile Bacacier 18/76, thickness 0,63 mm

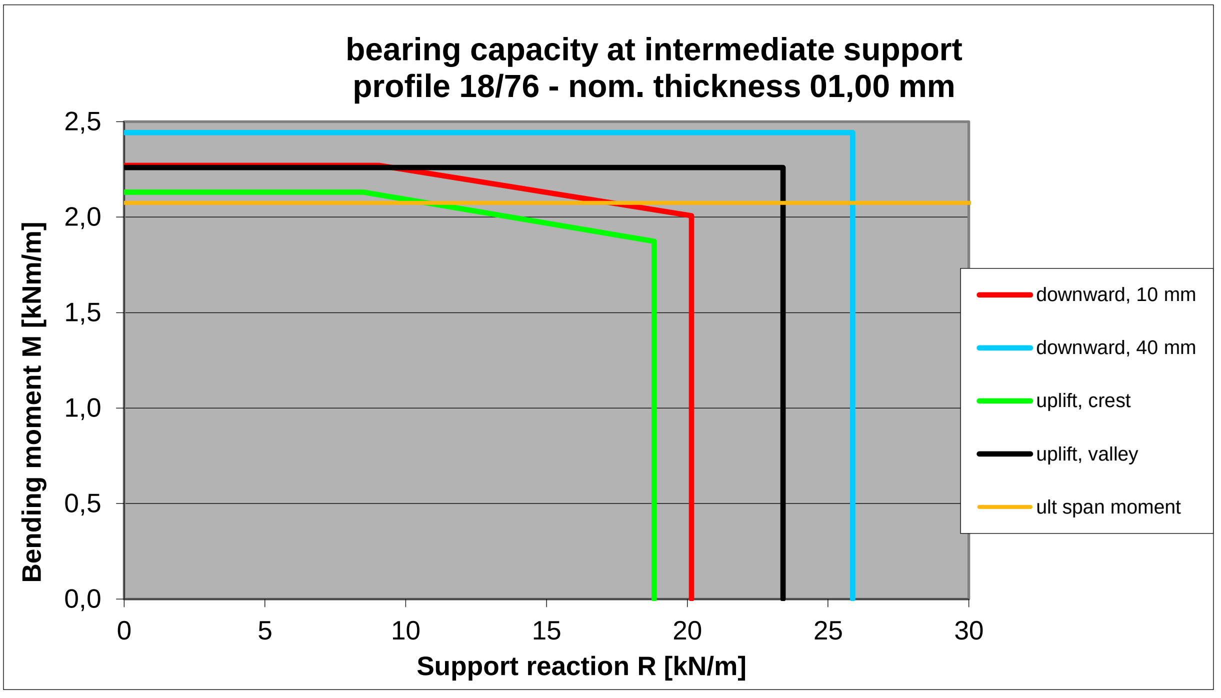

Fig. 34: Comparison M/R-interaction for different support conditions, profile Bacacier 18/76, thickness 1,00 mm

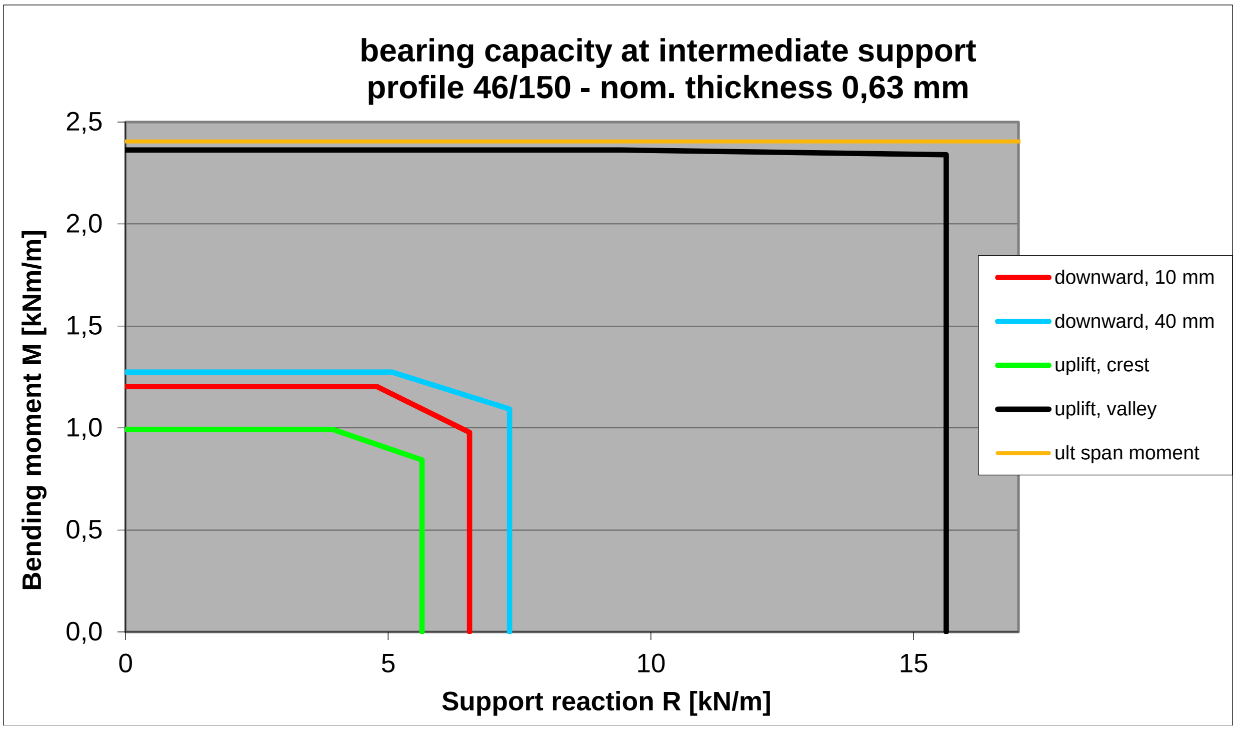

Fig. 35: Comparison M/R-interaction for different support conditions, profile Bacacier 46/150, thickness 0,63 mm

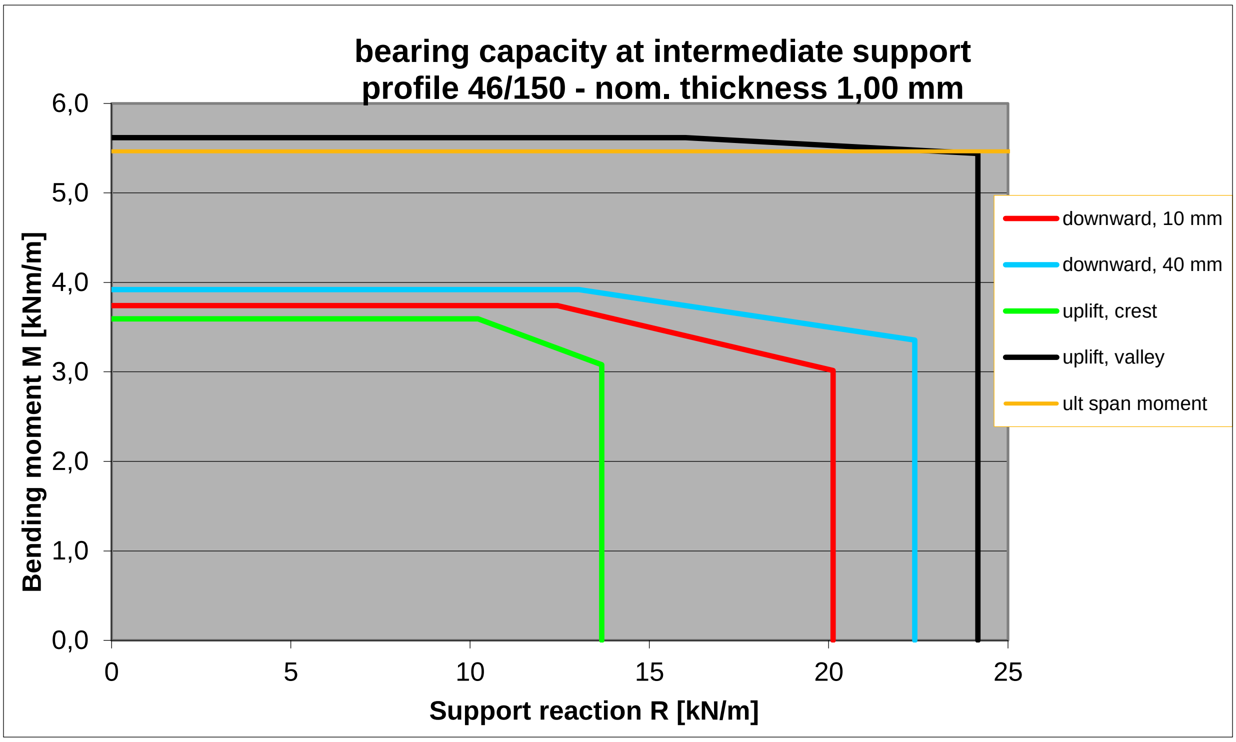

Fig. 36: Comparison M/R-interaction for different support conditions, profile Bacacier 46/150, thickness 1,00 mm

The reduction of the ultimate bending moment is influenced by the following parameters:

- R/t-ratio of the part of the cross section which is in contact to the support
  The profile 18/76 is more favourable than the profile 46/150. The thicker the sheet the smaller the influence of the support reaction. Thin sheets are very sensitive to local loads.

- Pitch of the cross section = length of the wave
  The profile 18/76 is more favourable than the profile 46/150. The larger the pitch the bigger the influence of the support reaction. The wave length represents the span length of the “bridge” which leads the local loads into the webs of the profile.

- Width of support, type of “support”
  The width of the support has also an influence on the M/R-interaction, but this influence is not very big. A support width of 40 mm is a little bit better than the support width 10 mm. The punctual “support” by the heads of the screws (uplift load, fixing on crest) is even less resistant as the linear support performed by a purlin or wall rail.

- Size of the support reaction/load, location and direction of the load
  The slope of the interaction relations shows the sensitivity of the cross section against local loads. Furthermore the fact, if the load/support reaction acts as pressure or as tension, plays a very important roll. If the support reaction acts as a tension force on the cross section, there is no effect on the bending moment.

The intermediate support tests for uplift load with fixing in the valley don’t show an interactive influence of the line load on the bending moment. Since the line load is introduced as a tension force on the cross section, the bending moment is not reduced compared to the bending moment capacity in span: On the one hand, the black lines are horizontal, this means, that the bending moment capacity is not reduced with increasing support reaction. On the other hand, the black lines are on the same level than the reference value ultimate span moment – independently of the profile and the sheet thickness.

If the line load/support reaction acts as compression force on the cross section – that is the case at internal supports under downward loading as well as under uplift loading with fixing in the crest -, the bending moment at internal supports is often considerably smaller than the bending moment in span (reference value). For great ratios R/t and even more for relatively small sheet thicknesses – for instance profile 46/150 , thickness 0,63 mm –, the bending moment at internal support drops to 40% of the bending moment capacity in span. But for small ratios R/t and relatively great thickness – for instance profile 18/76, thickness 1,0 mm – there is no reduction compared to the bending moment capacity in span. This profile is not sensitive against local loads; the interaction relations are more or less horizontal and on the same level like the reference value.

4.7 End support tests for downward loading

The tests are executed conform to the EN 1993-1-3 and are defined in the drawing below. The load is applied near to the interesting support using a steel plate and timber blocks; so, the load is introduced in the valleys in order to avoid prior failure in the span caused by local deformations and local buckling.

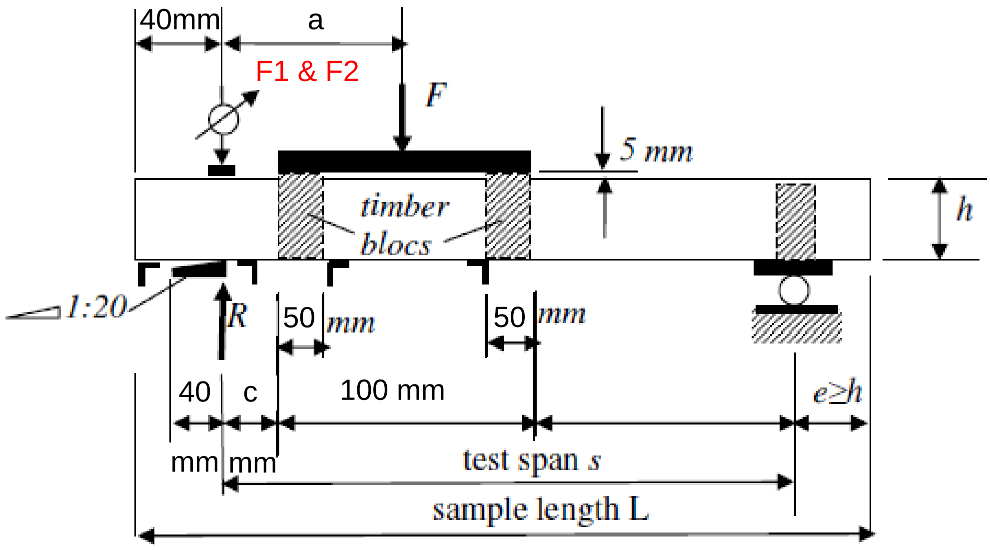

Fig. 37: Test setup end support tests for downward loading

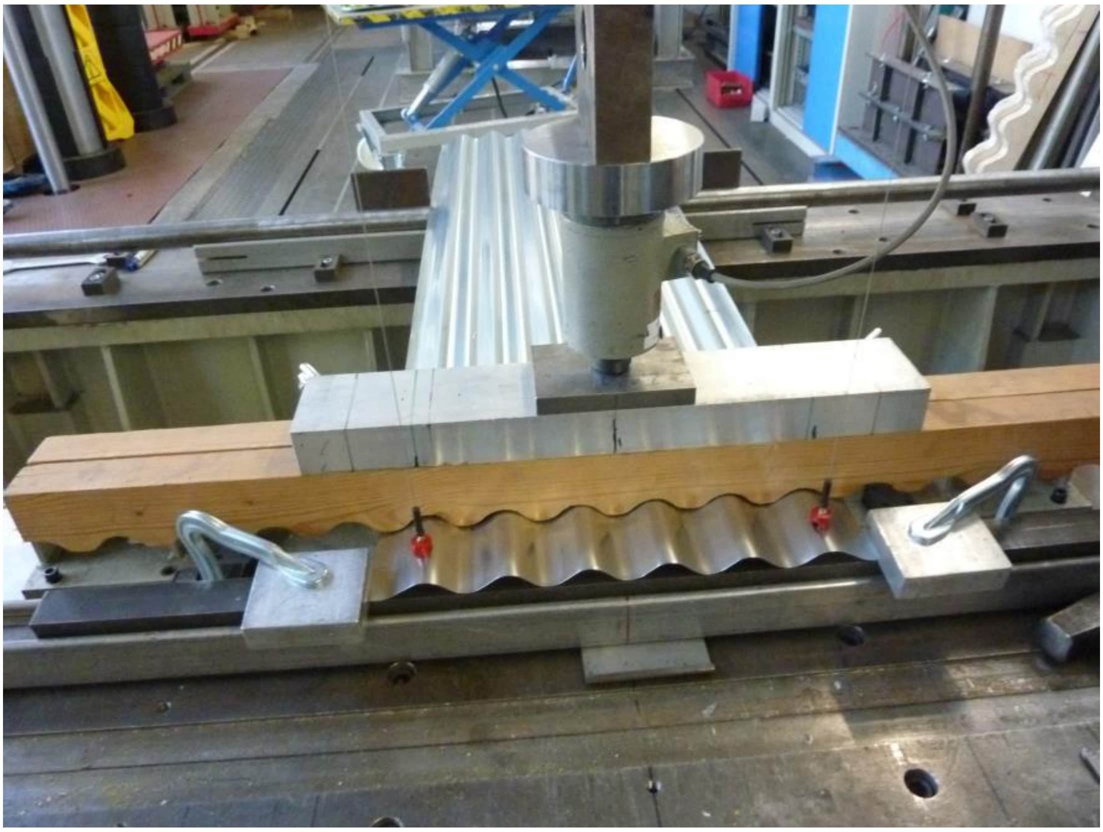

Fig. 38: Test setup end support test for downward loading

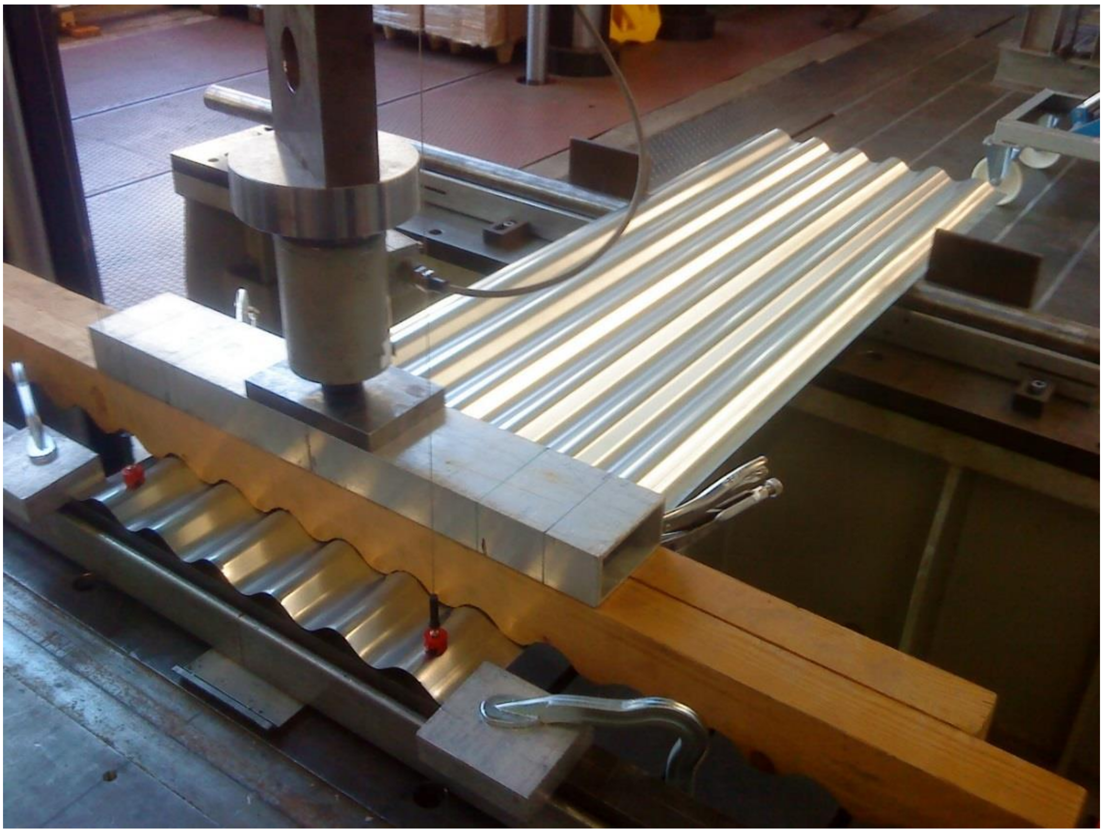

Fig. 39: Test setup end support test for downward loading

The characteristic support reaction is determined with the following formula:

$$R_{w,Rk,A} = F_{u,k} / b_V * (s-a) / s$$

with:

$R_{w,Rk,A}$	characteristic support reaction at end support (kN/m)
$F_{u,k}$	characteristic load in kN (including preload)
b_V	width of the test specimen
a	distance between load axis and support axis
s	span length

The self-weight of the test specimen is neglected.

The following photos show the failure of the test specimens which is dominated by local deformations at the support and local buckling of the compressed parts of the cross section in the load axis, where the bending moment becomes a maximum.

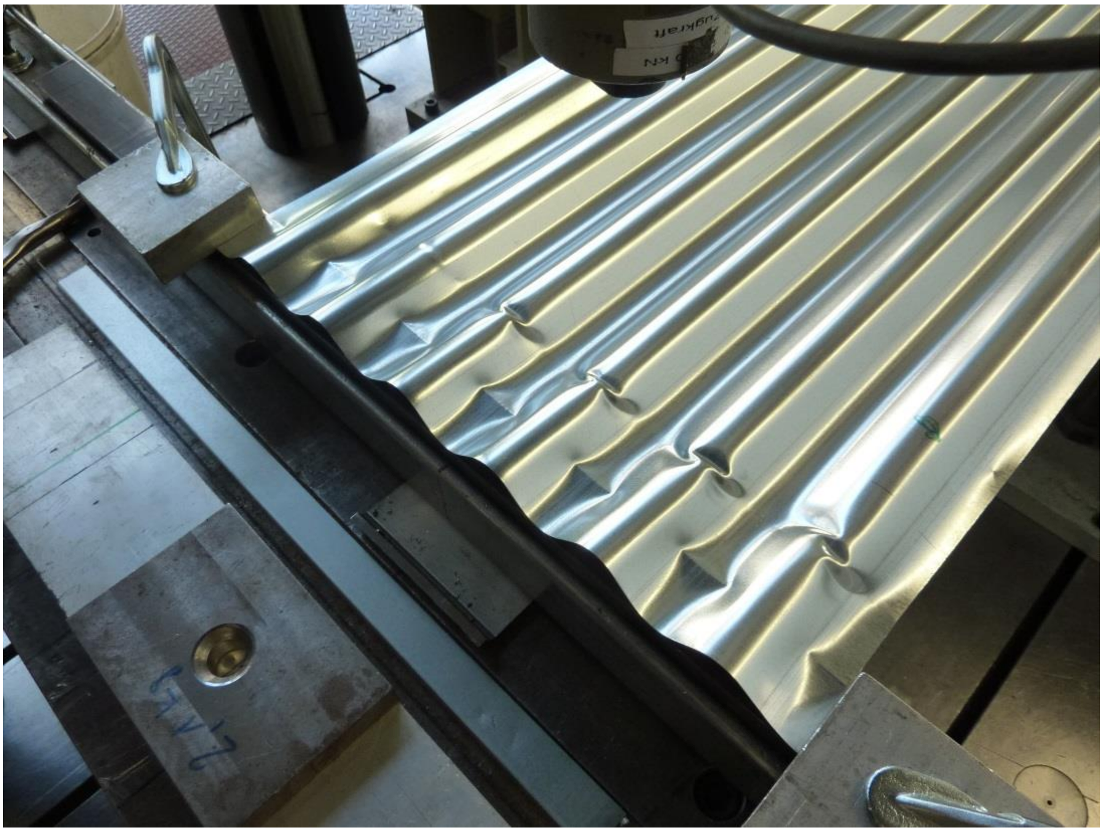

Fig. 40: Successive failure at support by local deformations and in the load application area by local buckling due to the bending moment

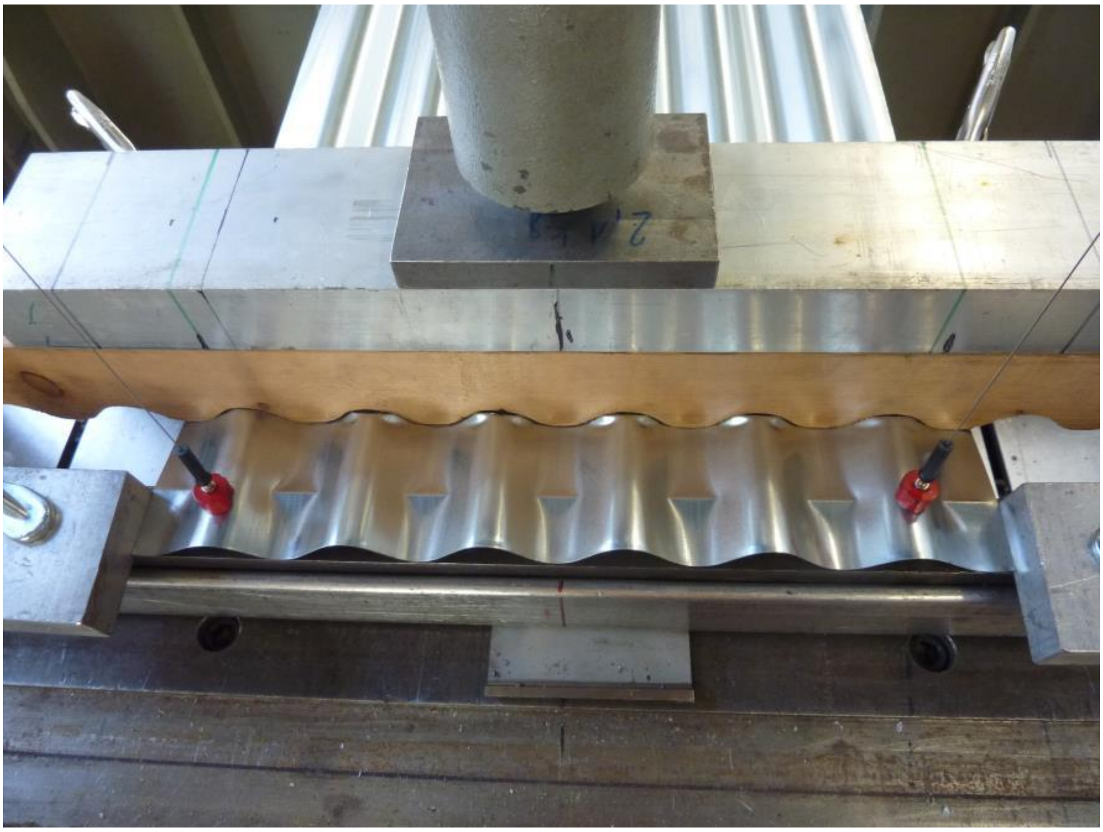

Fig. 41: Successive failure at support by local deformations and in the load application area by local buckling due to bending moment

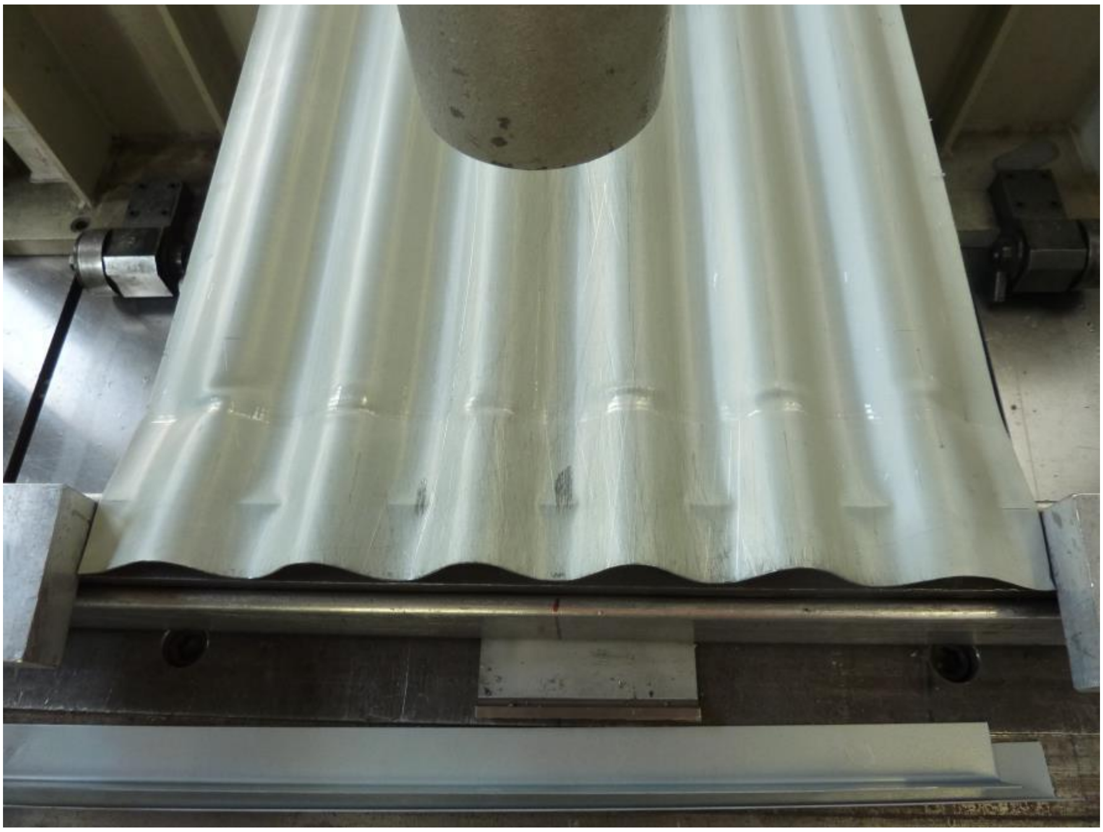

Fig. 42: Successive failure at support and in the span. After local buckling in span, the load and the local deformations at support cannot be increased.

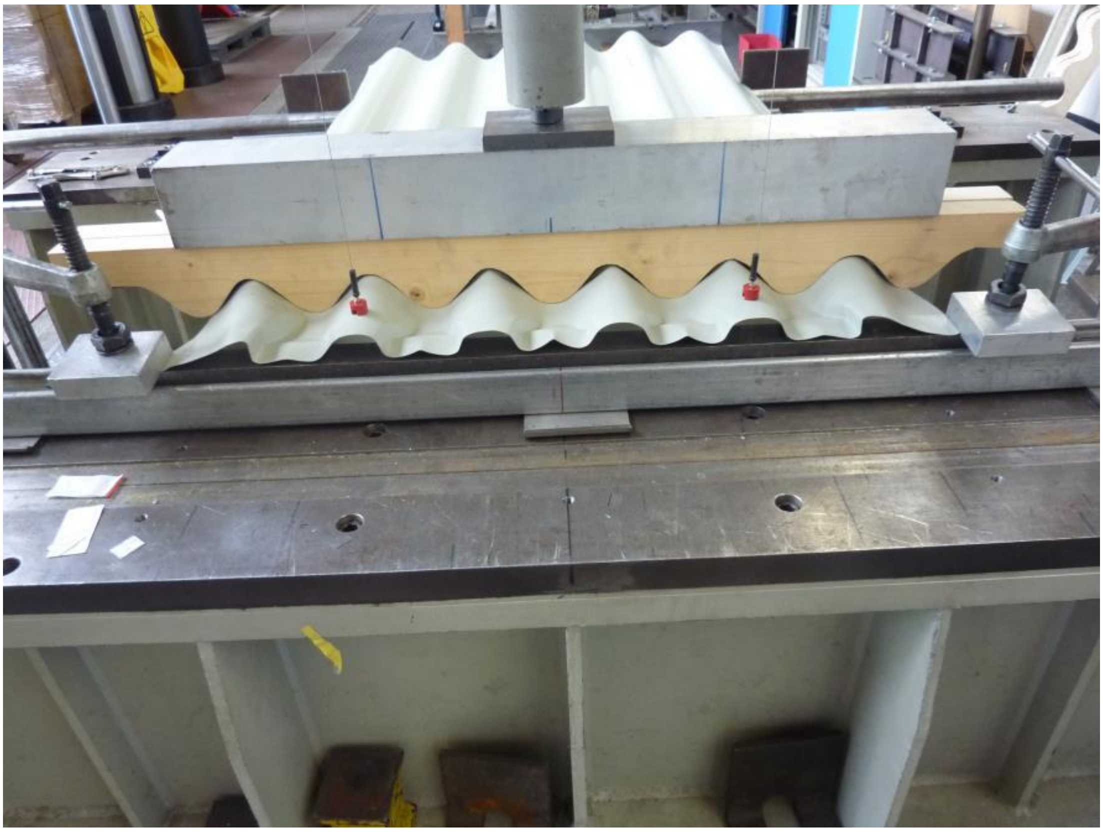

Fig. 43: Sukzessive failure at support by local deformations and in the load application area by local buckling due to bending moment

The detailed test evaluation for downward loading is presented in the annex page 18. Table 8 gives the final results of these tests.

Profile	nominal thickness t mm	support width $L_{a,A}$ mm	overhang c mm	support reaction $R_{w,Rk,A}$ kN/m
Bacacier 18/76	0,63	0	40	18,13
	1,00	0	40	40,09
Bacacier 46/150	0,63	0	40	13,26
	1,00	0	40	39,20

Table 8: Characteristic support reaction at end support under downward loading

4.8 Load tests to determine the shear resistance

The tests to determine the shear resistance of the corrugated sheets are similar to the end support, but with modified support configuration. The support is equipped with timber blocks to avoid local deformation at the support. The test conditions are defined in the drawing below. The load is applied near to the support using a steel plate and timber blocks; so, the load is introduced in the valleys in order to avoid prior failure in the span caused by local deformations and local buckling.

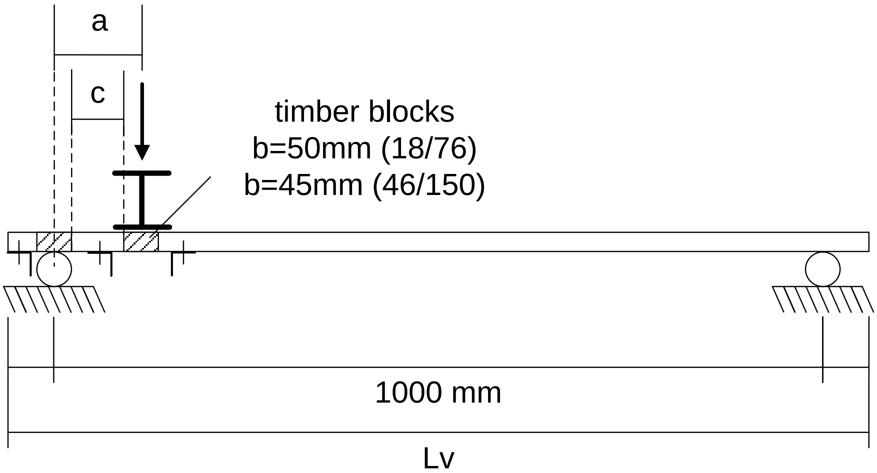

Fig. 44: Test setup to determine the shear resistance of the sheets

Fig. 45: Test setup to determine the shear resistance of the sheets

The maximum shear force at the support is determined with the following formula:

$$V_{w,Rk} = F_{u,k} / b_V * (s-a) / s$$

with:

$V_{w,Rk}$ characteristic shear force at end support (kN/m)

$F_{u,k}$ characteristic load in kN (including preload)

b_V width of the test specimen

a distance between load axis and support axis

s span length

The self-weight of the test specimen is neglected.

The following photos show the failure of the test specimens which is dominated by local buckling of the compressed parts of the cross section in the load axis, where the bending moment becomes a maximum. No local deformations at the support are visible.

Fig. 46: Failure by local buckling in span in the zone with maximum bending moment

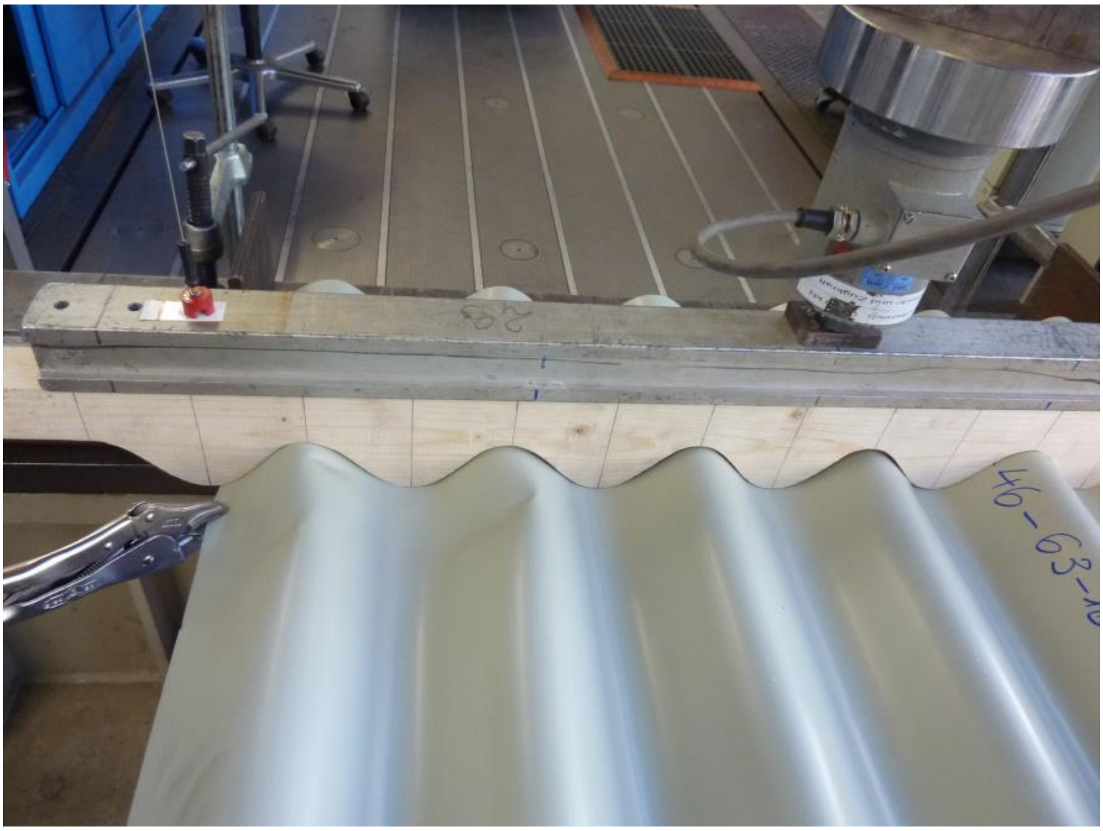

Fig. 47: Failure by local buckling in span in the zone with maximum bending moment

The detailed test evaluation is presented in the annex page 18. Failure occurred by local buckling in span due to bending moment. The applied load was limited by bending failure, and no shear failure at support was achieved. Therefore, the test results are a lower estimation of the shear resistance of the corrugated profiles. It was seen that the load was always above the end support test results. So the shear strength is not the criteria which governs the strength of the profile. Table 8 gives the final results of these tests in comparison with the end support tests.

Profile	nominal thickness t mm	support width $L_{a,A}$ mm	overhang c mm	support reaction $R_{w,Rk,A}$ kN/m	shear resistance $V_{w,Rk}$ kN/m
Bacacier 18/76	0,63	0	40	18,13	18,77
Bacacier 46/150	0,63	0	40	13,26	16,78

Table 9: Shear resistance of the corrugated sheets compared with the characteristic support reaction at end support under downward loading

5. References

- [1] Deliverable D2.3: Test report Corrugated Sheets, KIT, 31.05.2015
- [2] EN 1993-1.3: Eurocode 3 – Design of steel structures. Part 1.3: General rules – supplementary rules for cold-formed members and sheeting

Annex: Detailed test evaluation