GRISPE

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

Working Package 2

Background and draft annexes for EN 1993-1-3 for assembled profiles

31st October 2015

Deliverable D 2.5

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

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PU	*Public*	
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RE	*Restricted to a group specified by the Beneficiaries*	
CO	*Confidential, only for Beneficiaries (including the Commission services)*	***x***

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Deliverable	
D 2.5 WP2 Background and draft annexes for EN 1993-1-3 for assembled profiles	***Due date : 31.10.2015*** ***Completion date: 31.12.2015***

1. Introduction

There are three types of assemblies (see fig. 1). The resistance of the first joint is equal to a single profile. The resistance by the second and third joint is higher than the load-bearing capacity of a continuous profile. The second joint and third joint are often used to repair buildings or to solve deflection in span. A second reason is to improve the load-bearing capacity below snow accumulation

In DIN 18807 there is a design procedure for the fasteners and the web for the clamped joint. In prEN 1090-4 the same procedure is mentioned.

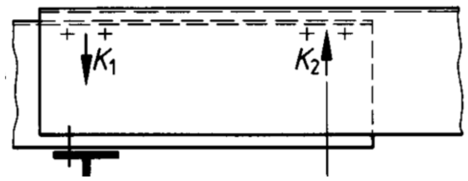
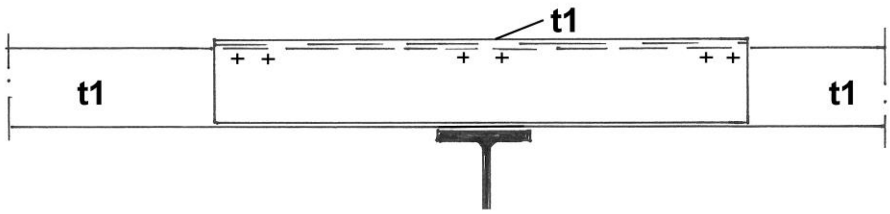
Clamped joint, moment resisting connection (EN 1090-4)	
Overlap joint	
Continuous profile with local reinforcement	

Fig.1: Three various profile assemblies

The failure of these profiles at internal support occurs through local impression and buckling of the compressed parts. By DIN (EN 1090-4) joint the distance of the fasteners is an important influence parameter.

The aim of the GRISPE project is to develop a design model to calculate the load-bearing capacity of the three different assemblies. Therefore internal support tests for gravity loading were performed. In the test report D 2.3 [3] the test range and the results are documented. The tests are evaluated and the ultimate bending moment was determined in D 2.4 [4].

2. Acquired data through GRISPE project

In the GRISPE project a large test program was performed to determine the load-bearing capacity of the different types of assemblies. In the following table the performed tests are documented.

Type of test	Thickness [mm]	Type	Support width [mm]	Span [mm]		Number of tests	
				JI D_137	JI D_158	JI D_137	JI D_158
Internal support tests with gravity loading	0.75	Continuous profile (C)	60	800	800	2	2
				2400	2800	2	2
			160	800	800	2	2
				2400	2800	2	2
	1.00		60	800	800	2	2
				2800	3200	2	2
			160	800	800	2	3
				2800	3200	2	2
	0.75	Joint according to DIN 18807 (DIN)	60	800	800	2	2
				2400	2800	2	2
			160	800	800	2	2
				2400	2800	2	2
	1.00		60	800	800	2	2
				2800	3200	2	2
			160	800	800	2	2
				2800	3200	2	2
	0.75	Overlap (OL)	60	800	800	2	2
				1300	800	1	2
				2400	2800	2	2
			160	800	800	2	2
				2400	2800	2	3
	1.00		60	800	800	2	2
				2800	3200	2	2
			160	800	800	2	2
				2800	3200	2	2
	0.75	Continuous profile with local reinforcement (CR)	60	800	800	2	2
				2400	2800	2	2
			160	800	800	2	2
				2400	2800	2	2
	1.00		60	800	800	2	2
				2800	3200	2	2
			160	800	800	2	2
				2800	3200	2	2

Table 1: Tests performed

Two different profiles in two thicknesses (different d/r-ratio) were tested. They are shown in Figure 4 and 5.

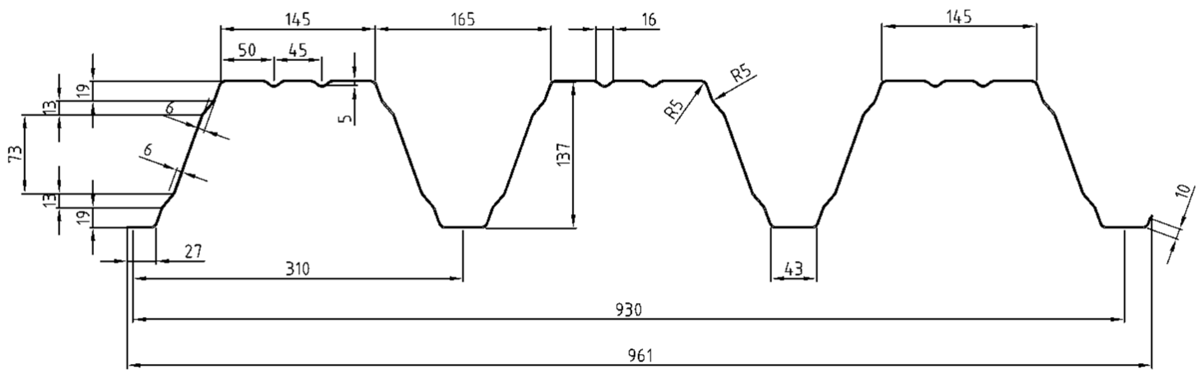


Fig. 2: Cross section of the profile JI D_137-310-930

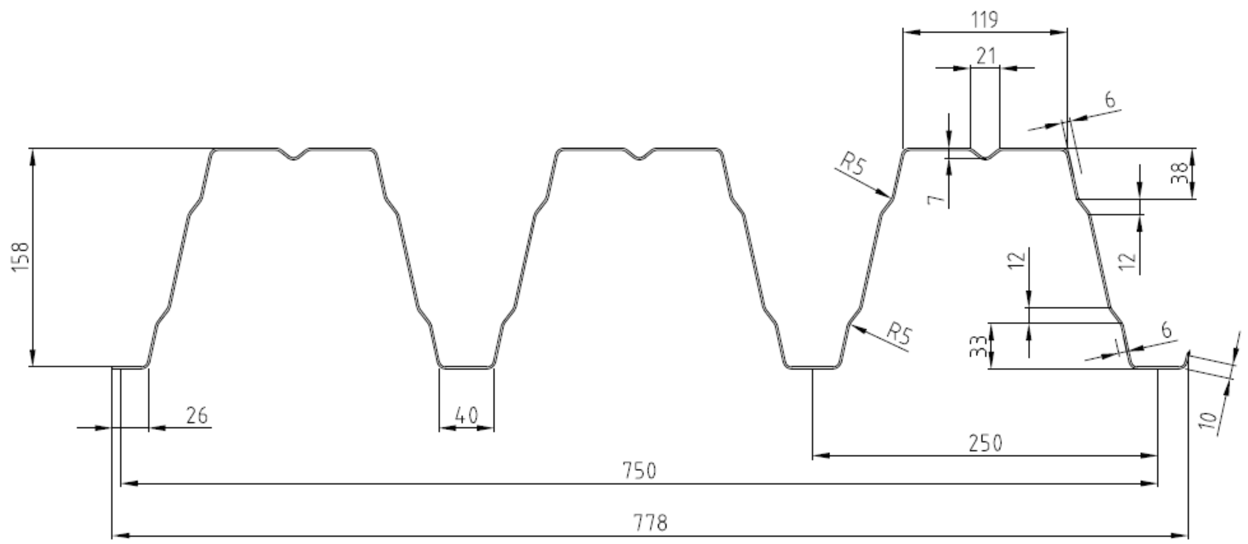


Fig. 3: Cross section of the profile JI D_158-250-750

Detailed information of the test setups and the test results are documented in [3].
The test setup and main results of the interpretation and analysis of the test results are listed again in this document. They are as follows:

Internal support test:

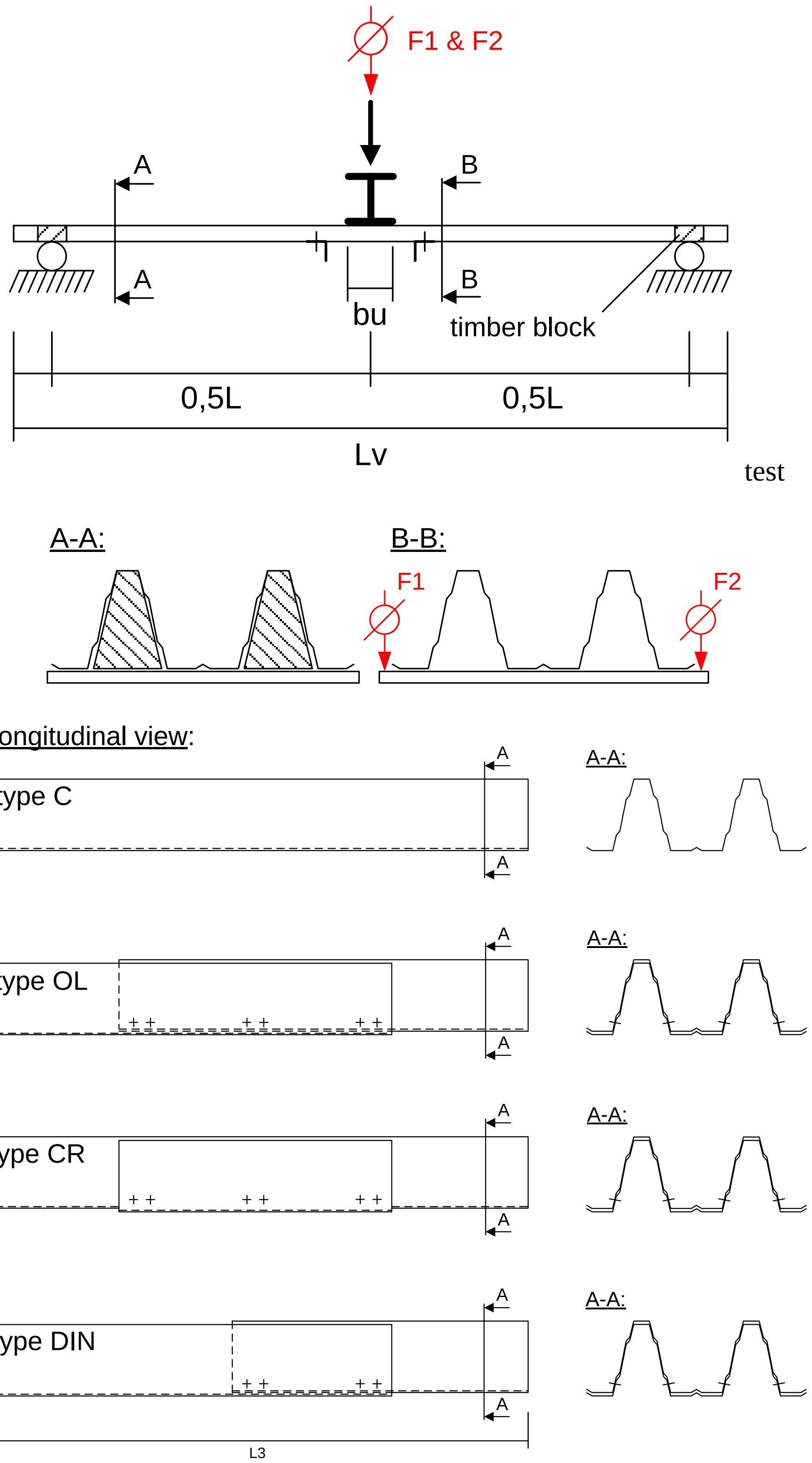


Fig. 4: Test setup internal support test

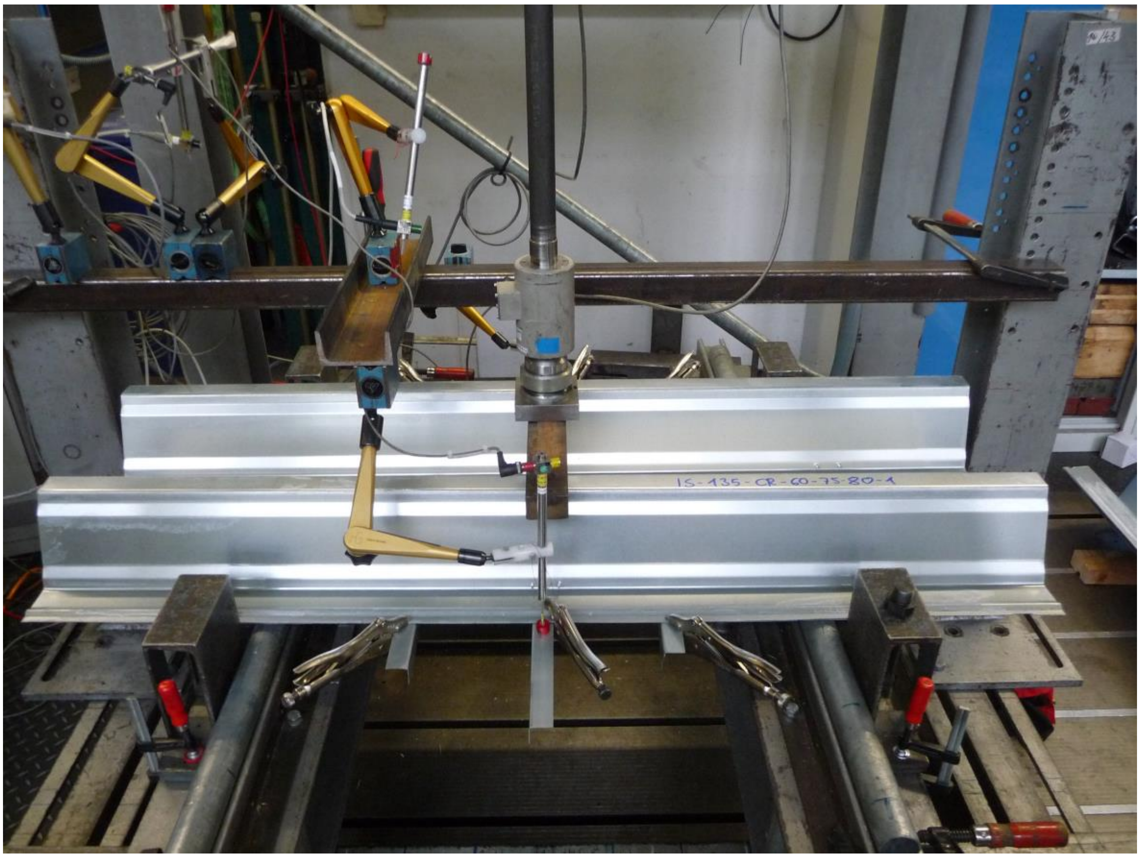
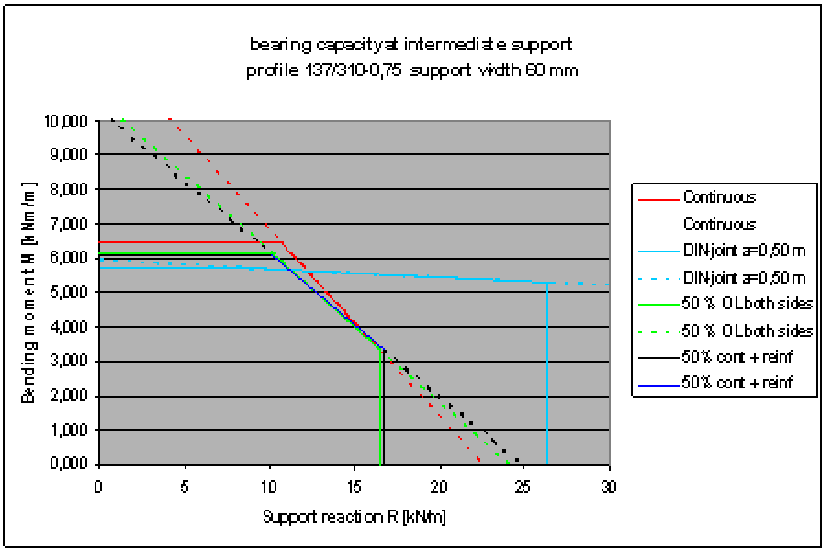


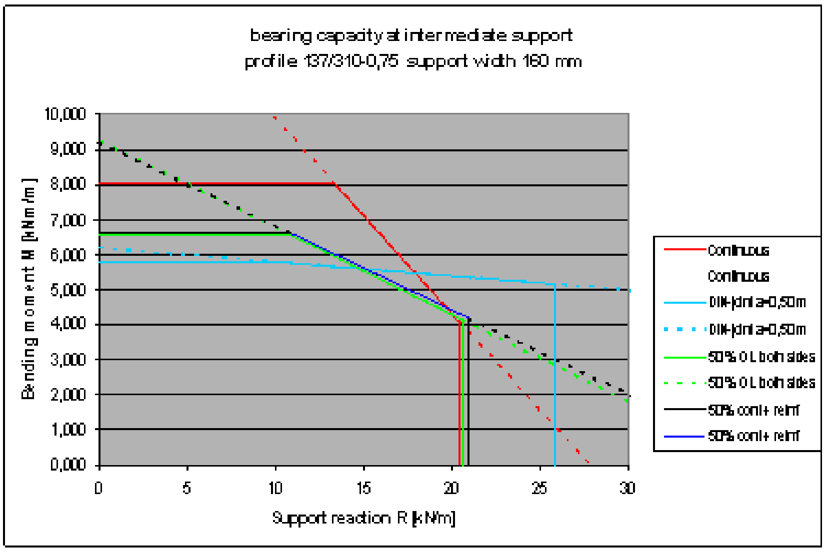
Fig. 5: Picture of the test setup



Support width 60 mm

Cont:	M = 6,46 kNm/m	100 %
DIN:	M = 5,70 kNm/m	88 %
OL:	M = 6,12 kNm/m	95 %
CR:	M = 6,11 kNm/m	95 %

Fig. 6: Graphic view of the test results of profile 137/310-0.75, bu = 60 mm



Support width 160 mm

Cont:	M = 8,03 kNm/m	100 %
DIN:	M = 5,82 kNm/m	73 %
OL:	M = 6,55 kNm/m	82 %
CR:	M = 6,60 kNm/m	82 %

Fig. 7: Graphic view of the test results of profile 137/310-0.75, b_u = 160 mm

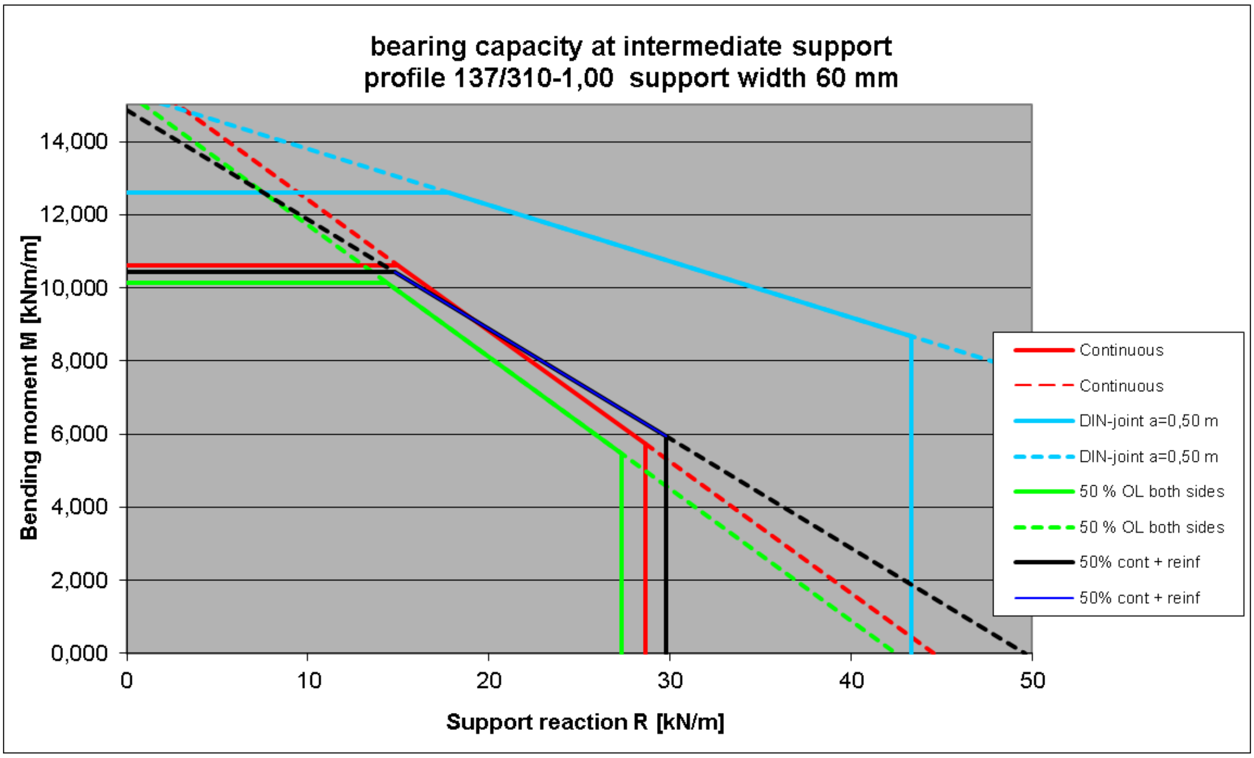


Fig. 8: Graphic view of the test results of profile 137/310-1.00, b_u = 60 mm

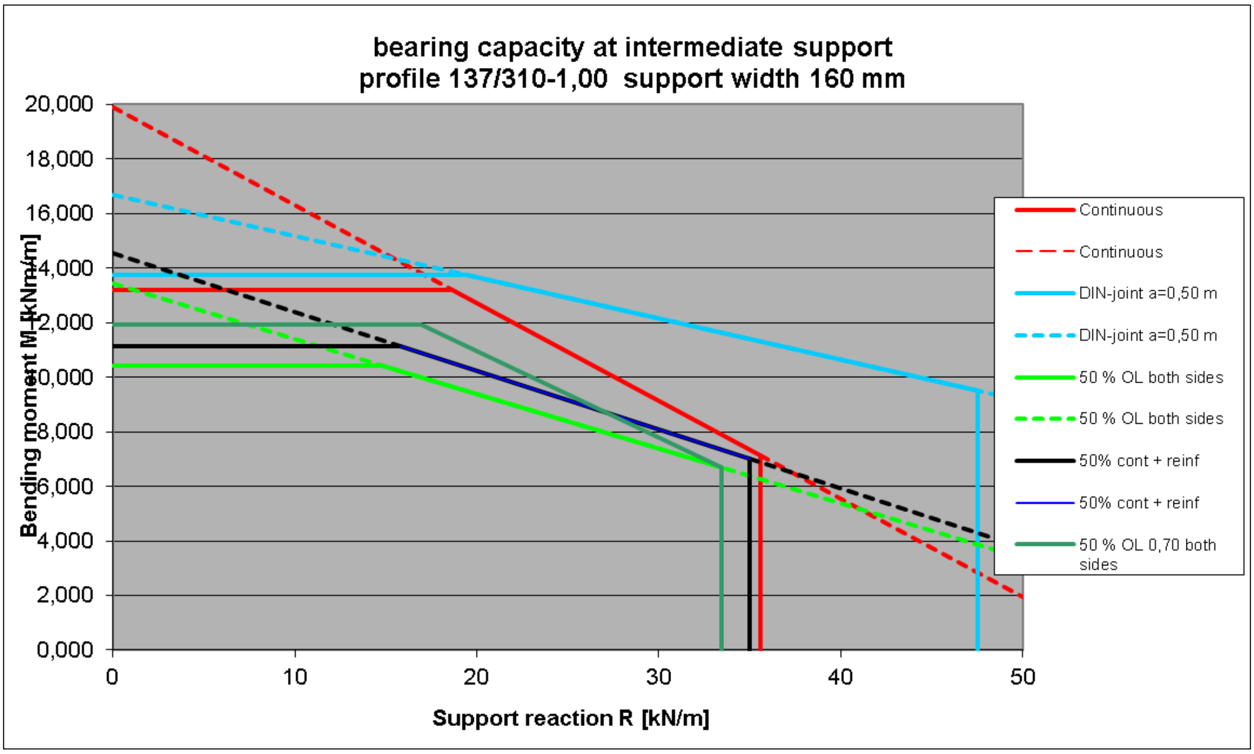


Fig. 9: Graphic view of the test results of profile 137/310-1.00, b_u = 160 mm

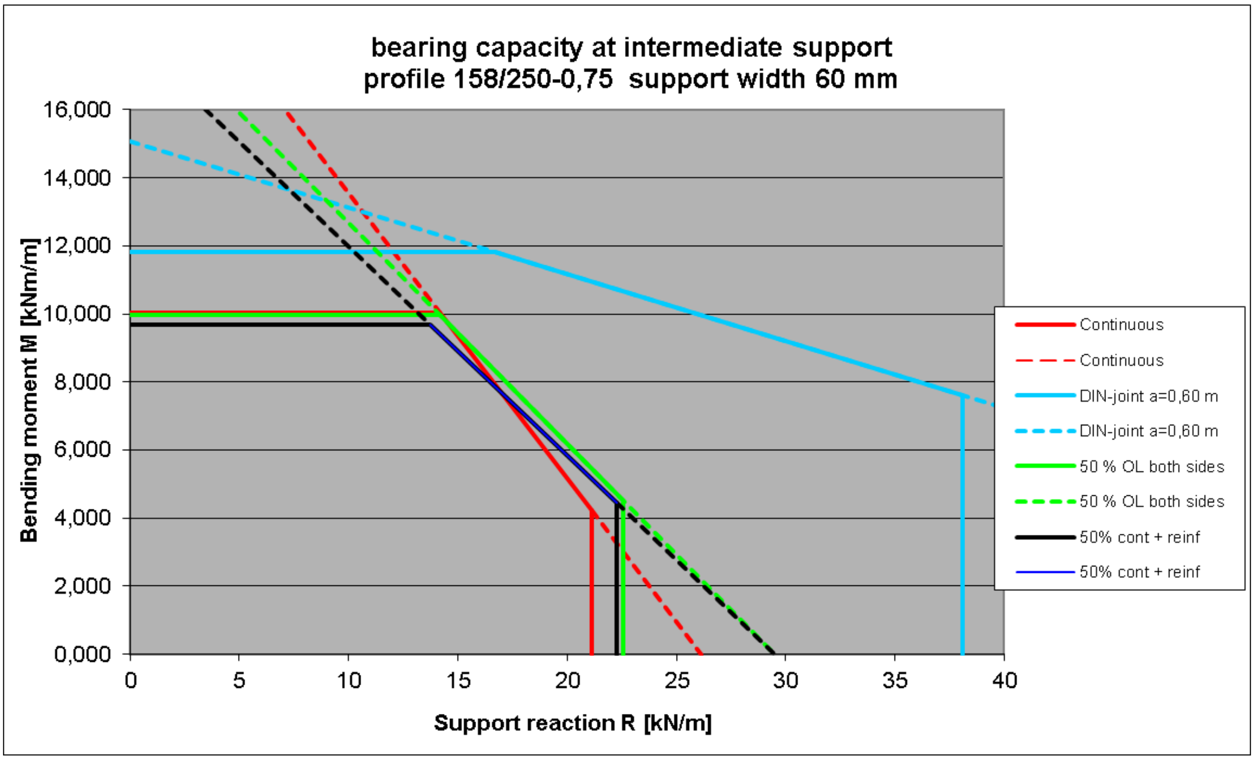


Fig. 10: Graphic view of the test results of profile 158/250-0.75, b_u = 60 mm

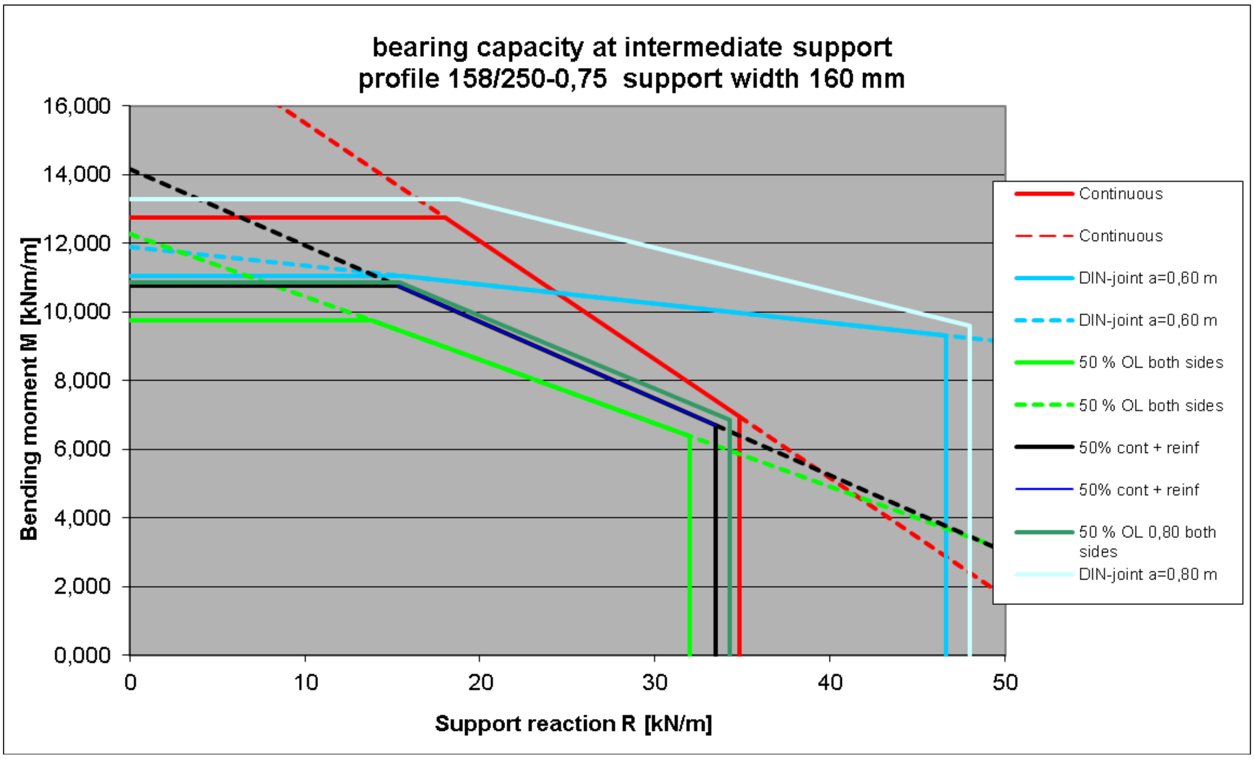


Fig. 11: Graphic view of the test results of profile 158/250-0.75, b_u = 160 mm

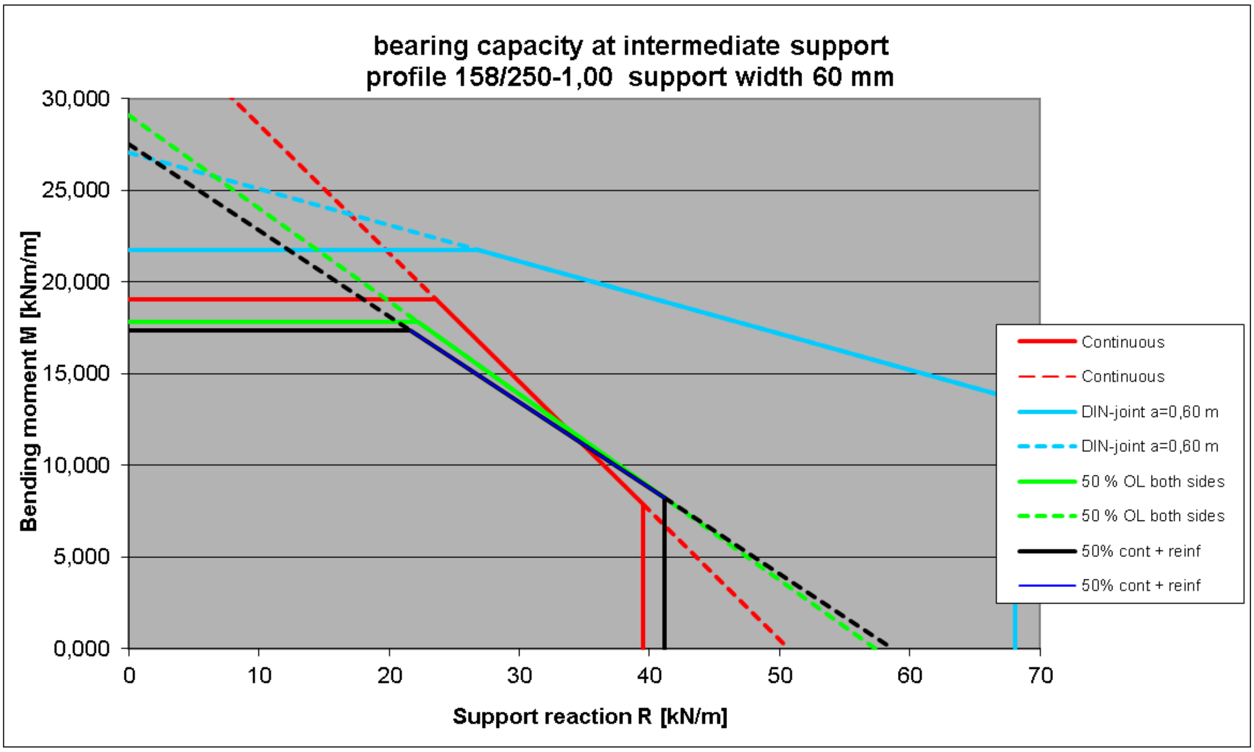


Fig. 12: Graphic view of the test results of profile 158/250-1.00, b_u = 60 mm

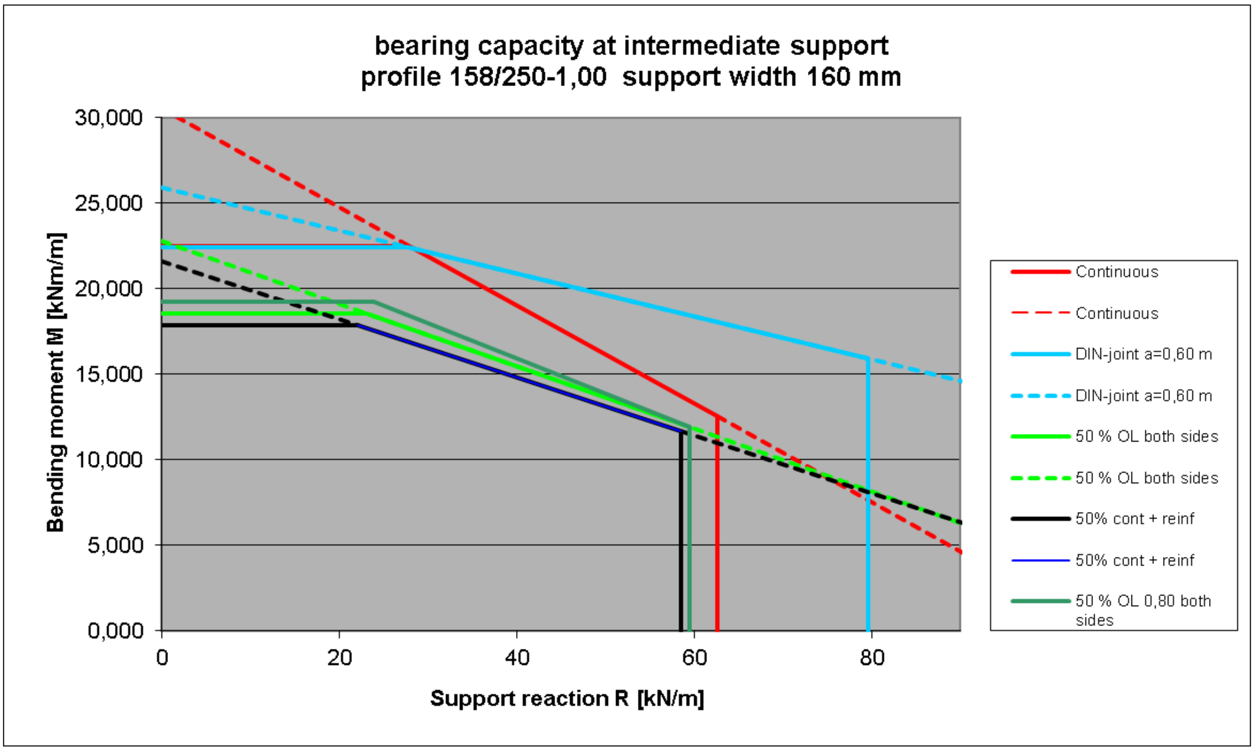


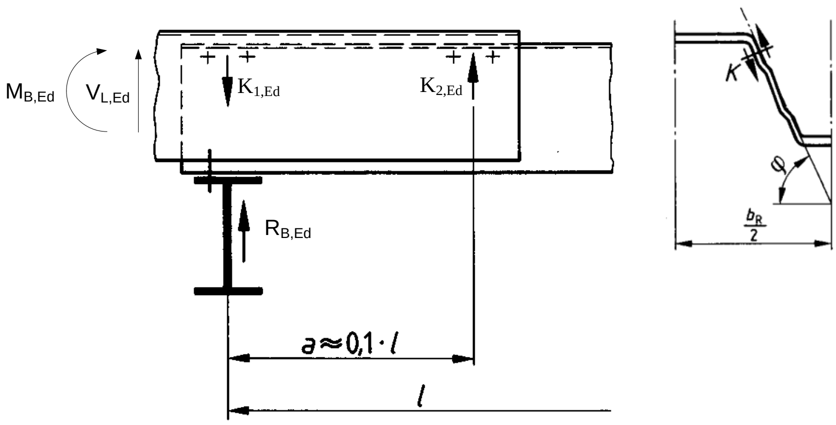
Fig. 13: Graphic view of the test results of profile 158/250-1.00, b_u = 160 mm

More detailed information of the analysis and interpretation of the test results are documented in [4].

3. Calculation method for assembled profiles

Based on the test evaluation and interpretation [4] we suggest the following design method for DIN joints (DIN):

1. cantilever above



a) Verification of the profile with the design resistance values ($M_{Rd,B}$, $R_{w,Rd,B}$) of the continuous profile in the support axis taking into account the influence of support reaction (M-R-interaction).

b) Check of the free end of the cantilever, if the line load F_{Ed} introduced by the connections K_i may create web crippling

- Downward load = negative bending moment

web crippling at the end of the cantilever
$F_{Ed} = M_{B,Ed}/(a) < 0,5\ R_{w,Rd,B}$
$R_{w,Rd,B}$ is the ultimate support reaction at intermediate supports in the opposite profile position (in general negative position) for the max. support width, in general l_{aB} = 160 mm (determined in GRISPE [1], that the design resistance $R_{w.Rd,B}$(160 mm) is suitable for this verification)

- Uplift load = positive bending moment

No web crippling possible at the end of the cantilever

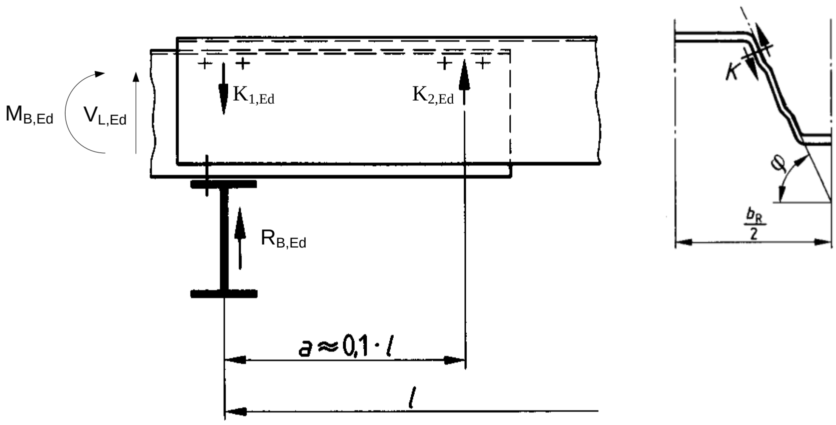
c) Verification of the connections K_{Ed}

$$K_{Ed} = \max K_i = \frac{\left|\frac{M_{B,Ed}}{a} + V_{L,Ed}\right|}{2 * \sin\varphi} * b_R \text{ (Verification in one web)}$$

$$\frac{K_{Ed}}{\Sigma F_{v,Rd}} \leq 1,0$$

with $\Sigma F_{v,Rd}$ shear resistance of the screws

2. cantilever underneath



a) Verification of the profile with the design resistance values ($M_{Rd,B}$, $R_{w,Rd,B}$) of the continuous profile in the support axis taking into account the influence of support reaction (M-R-interaction).

b) Check of the free end of the cantilever, if the line load F_{Ed} introduced by the connections K_i may create web crippling

- Downward load = negative bending moment

No web crippling possible at the end of the cantilever

- Uplift load = positive bending moment

No web crippling possible at the end of the cantilever

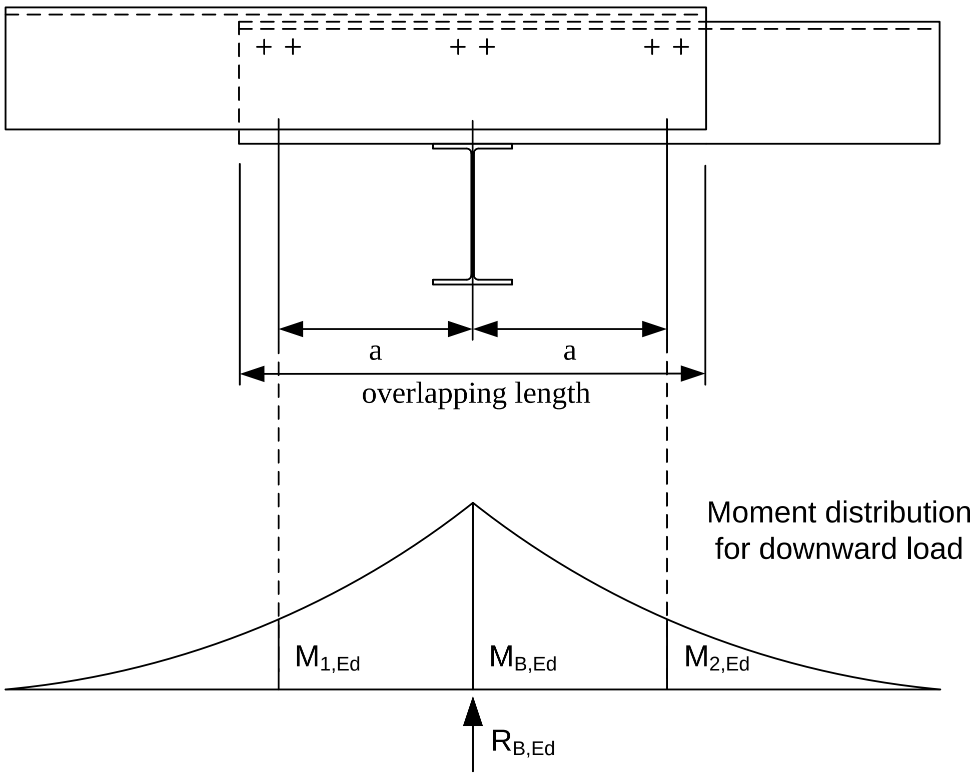
c) Verification of the connections K_{Ed}

$K_{Ed} = \max K_i = \frac{|M_{B,Ed}|}{2*a*\sin\varphi} * b_R$ (Verification in one web)

$\frac{K_{Ed}}{\Sigma F_{v,Rd}} \leq 1{,}0$

with $\Sigma F_{v,Rd}$ shear resistance of the screws

3. Overlap joint



a) Determination of the bending moment distribution under design loads like for continuous sheets (The influence of the higher bending stiffness at the overlapping area, which is partly compensated by the slip and/or elastic deformations at the connections, is neglected). Results: $M_{B,Ed}$; $R_{B,Ed}$; $M_{1,Ed}$; $M_{2,Ed}$

b) Verification of the profiles at the support axis with 90 % of the resistance of the overlapping profiles (factor 0,9 determined in GRISPE [1]) taking into account the influence of the support reaction (M-R-interaction):

$M_{B,ED} \leq 0{,}9 \sum M_{Rd,B}$; $R_{B,ED} \leq 0{,}9 \sum R_{wRd,B}$; M-R-interaction

c) Verification of the continuous profiles at the ends of the overlap with the bending moments $M_{1,Ed}$ or $M_{2,Ed}$ and the line loads introduced by the connections K_i: $F_{Ed} = M_{B,Ed}$ / (2a). Depending of the direction of the load F_{Ed} relative to the web of the profile, the M-R-interaction or the M-V-interaction has to be verified.

For downward load, F_{Ed} is acting as a tension force on the webs of the continuous profiles; M-V-interaction has to be verified.
For uplift load, F_{Ed} is acting as a compression force on the webs of the continuous profiles; M-R-interaction has to be verified.

In both load cases, the resistance values of the profile in the opposite position at intermediate supports apply for these verifications.

d) Check of the free end of the cantilever, if the line load F_{Ed} introduced by the connections K_i may create web crippling

- Downward load = negative bending moment

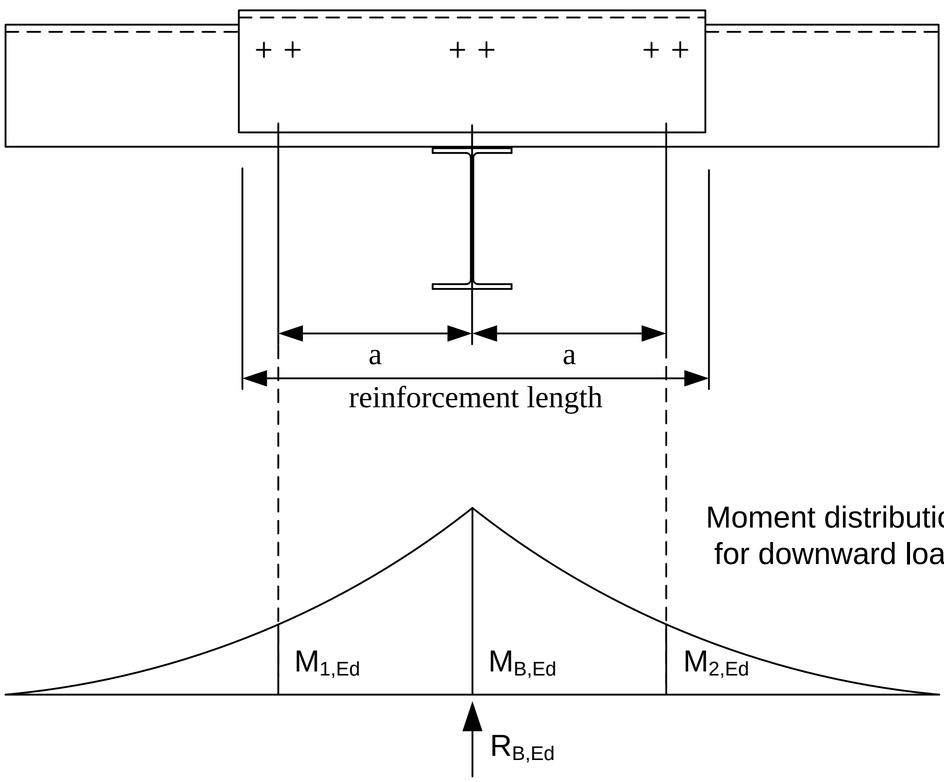
web crippling at the end of the upside cantilever
$F_{Ed} = M_{B,Ed}/(2a) < 0,5\ R_{w,Rd,B}$
$R_{w,Rd,B}$ is the ultimate support reaction at intermediate supports in the opposite profile position (in general negative position) for the max. support width, in general l_{aB} = 160 mm (determined in GRISPE [1], that the design resistance $R_{w.Rd,B}$(160 mm) is suitable for this verification)
No web crippling possible at the end of the cantilever underneath

- Uplift load = positive bending moment

No web crippling possible, neither at the upside cantilever nor at the cantilever underneath.

e) Verification of the connections K_{Ed}
with
$K_{Ed} = \max K_i = \frac{|M_{B,Ed}|}{4 * a * \sin\varphi} * b_R$ (Verification in one web)
$\frac{K_{Ed}}{\Sigma F_{v,Rd}} \leq 1,0$
with $\Sigma F_{v,Rd}$ shear resistance of the screws

4. Continuous profile with local reinforcement



a) Determination of the bending moment distribution under design loads like for continuous sheets (The influence of the higher bending stiffness at the overlapping area, which is partly compensated by the slip and/or elastic deformations at the connections, is neglected). Results: $M_{B,Ed}$; $R_{B,Ed}$; $M_{1,Ed}$; $M_{2,Ed}$

b) Verification of the profiles at the support axis with 90 % of the resistance of the overlapping profiles (factor 0,9 determined in GRISPE [1]) taking into account the influence of the support reaction (M-R-interaction):

$M_{B,ED} \leq 0{,}9 \sum M_{Rd,B}$; $R_{B,ED} \leq 0{,}9 \sum R_{wRd,B}$; M-R-interaction

c) Verification of the continuous profile at the ends of the overlap with the bending moments $M_{1,Ed}$ or $M_{2,Ed}$ and the line loads introduced by the connections K_i: $F_{Ed} = M_{B,Ed} / (2\ a)$. Depending of the direction of the load F_{Ed} relative to the web of the profile, the M-R-interaction or the M-V-interaction has to be verified.

For downward load, F_{Ed} is acting as a tension force on the webs of the continuous profile; M-V-interaction has to be verified.
For uplift load, F_{Ed} is acting as a compression force on the webs of the continuous profile; M-R-interaction has to be verified.
In both load cases, the resistance values of the profile in the opposite position at intermediate supports apply for these verifications.

d) Check of the free end of the cantilever, if the line load F_{Ed} introduced by the connections K_i may create web crippling

- Downward load = negative bending moment

web crippling at the end of both cantilevers
$F_{Ed} = M_{B,Ed}/(2a) < 0{,}5\ R_{w,Rd,B}$
$R_{w,Rd,B}$ is the ultimate support reaction at intermediate supports in the opposite profile position (in general negative position) for the max. support width, in general l_{aB} = 160 mm (determined in GRISPE [1], that the design resistance $R_{w.Rd,B}$(160 mm) is suitable for this verification)

- Uplift load = positive bending moment

No web crippling possible at the end of both cantilevers

e) Verification of the connections K_{Ed}
with
$K_{Ed} = \max K_i = \frac{|M_{B,Ed}|}{4 * a * \sin\varphi} * b_R$ (Verification in one web)
$\frac{K_{Ed}}{\Sigma F_{v,Rd}} \leq 1{,}0$
with $\Sigma F_{v,Rd}$ shear resistance of the screws

4. Conclusion

With the design procedure, documented in section 3, the practical engineer gets an easy to use tool to design the three types of assemblies (DIN joint, overlap joint and continuous profile with local reinforcement) for thin-walled steel sheets for roofing.

5. References

[1] EN 1993-1.3: Eurocode 3 – Design of steel structures. Part 1.3: General rules – supplementary rules for cold-formed members and sheeting
[2] Deliverable D 2.1: Background Document. KIT, 30.11.2013
[3] Deliverable D 2.3: Test report. Assembled profiles. KIT, 31.05.2015
[4] Deliverable D 2.4: Test analysis and interpretation. Assembled profiles. IFL, 31.10.2015