GRISPE PLUS

VALORISATION OF KNOWLEDGE
FOR SPECIFIC PROFILED STEEL SHEETS

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DESIGN MANUAL FOR ASSEMBLED PROFILES

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FINAL VERSION

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SUMMARY

The purpose of this design manual is to present a new method of design by calculation for assembled profile on intermediate support as developed in the European project GRISPE.

The manual is based on the Eurocode principles in general and more specifically on the EN 1993-1-3 and EN 1993-1-5 Eurocodes.

This new method of design by calculation for assembled profile on intermediate support is based on tests carried out within the European GRISPE project (2013-2016).

The background of this method can be found in the GRISPE project's deliverables D2.1.

Chapter 1 details the type of profiles concerned, the state of the art, the main research results of GRISPE and the general design requirements and rules.

Chapter 2 outlines the preliminary considerations that must be taken into account during the predesign phases and the minimum technological requirements that have to be respected including support frame, profiles characteristics and assemblies.

Chapter 3 gives the basic technological requirements.

Chapter 4 lists the materials properties of the profiles and of the fasteners.

Chapter 5 gives the actions that must be considered (self-weight, etc) and their combinations.

Chapter 6 explains in detail the new design method (principles, field of application, and description of how to apply the different new formula).

Chapter 7 lists the specific design consideration not covered by the manual (Fire, Seismic, Environmental aspect, Thermal, Acoustic,etc.)

Chapter 8 gives practical examples of the new design method.

A bibliography and the amendment proposal for EN 1993-1-3 is included.

PREFACE

This Design manual have been carried out with the support of RFCS funding n°754092.

This new design method has been presented at the evolution group of EN 1993-1-3 in 2016-2017 and is being considered for inclusion into the Eurocodes.

This Design manual has been written by Thibault RENAUX and has been discussed in a GRISPE PLUS working group composed by the following members:

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FIGURES & TABLES

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CONTENT

SCOPE OF THE PUBLICATION

The aim of this publication is to present the new design method for assembled profile, in accordance with [1] on intermediate support that has been proposed for inclusion in [2].

This design manual deals with currently occurring situations.

For specific issues (e.g. opening) or for exceptional situations (seismic, fire, etc.) it is necessary to follow the relevant clauses of the Eurocodes and/or [1].

NOTATIONS

In addition to notations of EN 1993-1-3, the following symbols are used:

K_{Ed}: load introduced by connection fasteners [kN]
a: length of overlap or reinforcement [m]

1. INTRODUCTION

1.1. Type of profiled steel sheets

This design manual deals with profiled steel sheets (see Figure 1.1 below) assembled on an intermediate support.

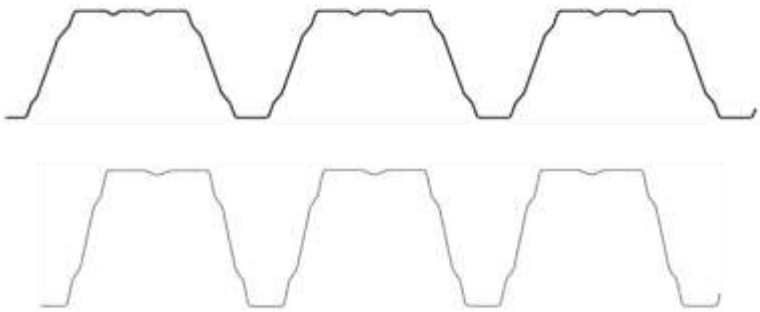


Figure 1.1 *– Typical geometry of profiled steel sheets.*

1.2. State of the art

The standard [2] doesn't cover the design of the continuity of a profiled steel sheet on support built up on the work site; in case of transport of profiles on two parts and then assembled together above a support, by a "clamped" joint, to recreate a continuous profile by overlapping (see figure 1.2.1 below) or in case of building repairs or to solve deflection in span.

In some case, snow and wind combined effect drives to local elevation of loading, i.e. a continuous profiled steel sheet on two span presenting a load accumulation on one of them. A practical solution consists to put a local reinforcement on the intermediate support in order to improve the characteristic resistance (see figure 1.2.1 below).

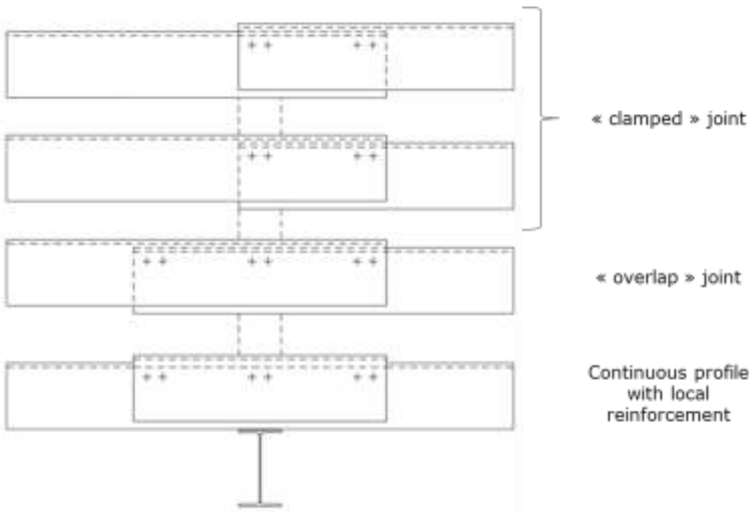


Figure 1.2.1 *– Assemblies of profiles steel sheets on intermediate support.*

These technics, very useful, need to be defined and a design method is required. It was the aim of one of the part of GRISPE Project.

In [3] there is a solution for overlapping profiles. They are only allowed at the supports. If powers are to be worn over contact, tests must be performed. In the overlapping field the resistance is equal to a continuous profile.
In the following figures 1.2.2 and 1.2.3, the two possibilities of this clamped joint are represented.

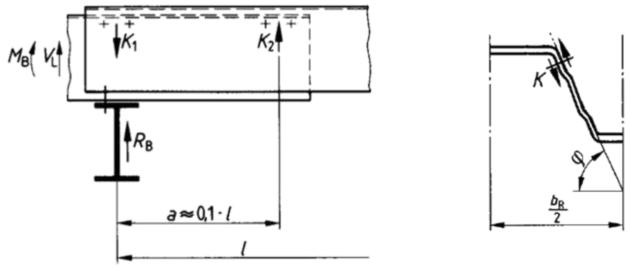


Figure 1.2.2 *– Overlapped profiles according to [3] with cantilevered end of profile underneath.*

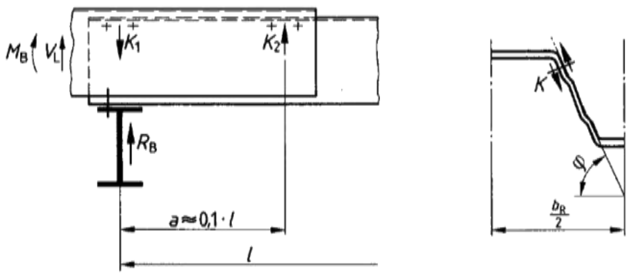


Figure 1.2.3 *– Overlapped profiles according to [3] with cantilevered end of profile on top.*

The force on the fastener is given to:

$$K = maxK_i = \frac{|M_B|}{2*a*\sin\varphi} * b_R \quad \text{(Figure 1.2.2)}$$

or

$$K = maxK_i = \frac{\left|\frac{M_B}{a}+V_L\right|}{2*\sin\varphi} * b_R \quad \text{(Figure 1.2.3)}$$

A maximum of two fasteners may be recognized in horizontal and vertical direction in each compound (maximum 4 fasteners). The required fastener edge spacing and hole spacing, see figure 1.2.4 below, shall be complied with

- hole spacing in direction of force: ≥ 3d and ≥ 20 mm;
- hole spacing at right angles to direction to force: ≥ 30 mm;
- hole spacing p: ≥ 4d and ≥ 40 mm and ≥ 10d.

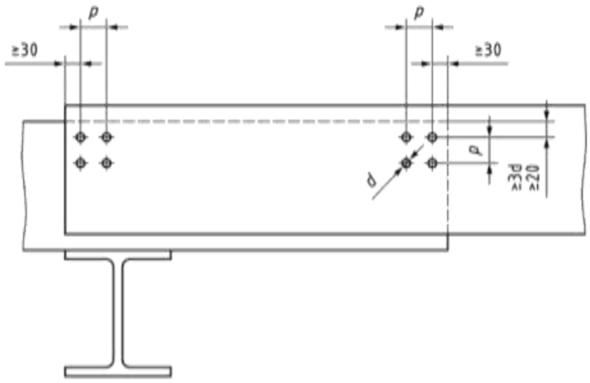


Figure 1.2.4 *– Distance of the fasteners according to [3] for a statically effective joint.*

In conclusion, there are design procedures in [3] and further in [4]. The design rules are similar to each other.

1.3. Main results of GRISPE

To confirm the procedure described in [3], there should be a series of tests at the clamped joint to confirm this design procedure. In addition there should be a number of tests at the overlap joint to acquire data about the load bearing capacity.

Two types of profiles (135/310 and 158/250), representative of the full range regarding the slope of the webs, were selected for testing as showed in figure 1.3 below.

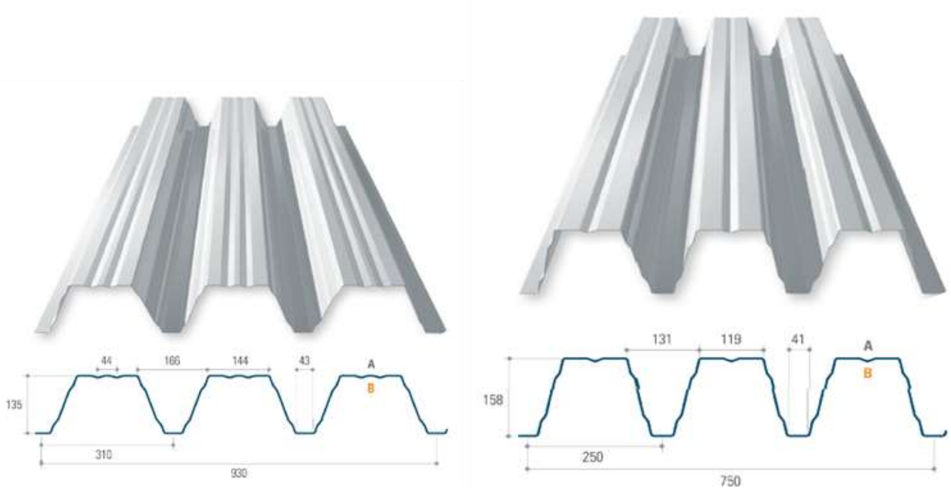


Figure 1.3.1 *– Tested trapezoidal profiles.*

A campaign of 128 tests was completed by tensile tests. Intermediate supports tests were carried out to study the load bearing behavior at intermediate supports (see figures 1.3.2 and 1.3.3), while tests with single sheets constituted the basis for the comparison with the different types of joints. Tests with overlaps according to [3] were executed to verify the design rules specified in [3] dealing with the fasteners.

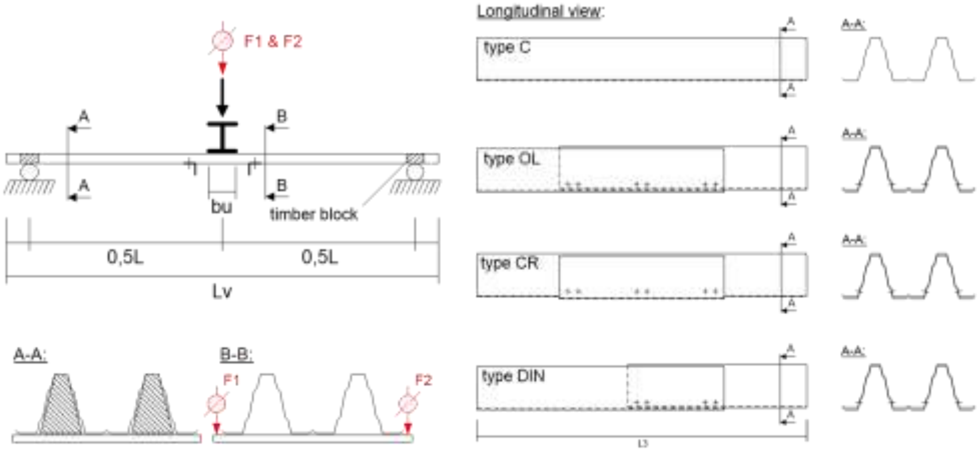


***Figure 1.3.2** – Schematic intermediate support test setup.*

***Figure 1.3.3** – Example of intermediate support test and collapse.*

The analysis and interpretation of the tests which had been carried out on assembled profile samples were reported in [5] and [6], and the comparison of assembly types was based on M/R diagrams established for each test (see figure 1.3.4).

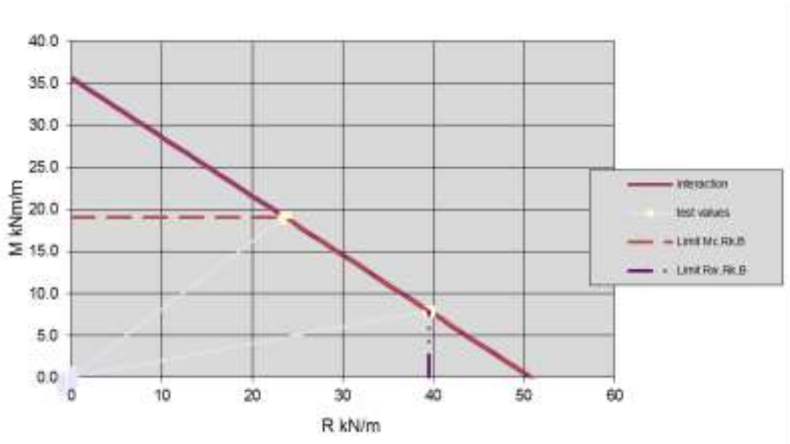


***Figure 1.3.4** – Example of interaction diagram obtained from intermediate support test.*

Calculations method were done for cantilever above and below, for overlap joints and for continuous profiles with local reinforcement. The principle is to decompose the bending moment in two force equal in intensity and direction but opposite direction. These forces are transmit to the assemblies via the fasteners.

Two others point were shown:

- In the cases of overlap joint with overlaps on both sides of the support and continuous profile sheet with local reinforcement, the sum of two profile is not exactly the sum of the two resistance of the profile but 1.8 x M_{Rd} if M_{Rd} is the bending resistance of one profile in bending;
- A specific collapse appear at the end of the profile (see figure 1.3.3) and thus it was justified by test that this resistance is 0.5 $R_{w,Rd}$.

For assembled trapezoidal profiles (statically effective overlapping), no data is available in the current version of [2]. It was decided that the calculation method developed could be transferred to the Eurocodes without further adjustments in a complementary annex.

1.4. General design requirements and rules

The following design method only offers a way for the calculation of the design resistance M_{Rd} and $R_{w,Rd}$ of a statically effective joint according to [7], its amendment [8] and corrigendum [9]. Design values of the effects of actions have to be evaluated in conformity to every relevant part of [10] and its corrigendum [11], [12] and its corrigendum [13] and amendment [14], [15] and its corrigendum [16] and amendment [17].

The succeeding procedure respects general rules given in [18] and its corrigendum [19] and amendment [20] and the basis of design defined in part 2 of [2] and its corrigendum [21].

2. PRELIMINARY CONSIDERATION

2.1. Field of application of the new design method

This manual presents a design method for determine the resistance of assembled profiles compliant to [1].

This method is established in the scope of minimum technological dispositions, see following paragraphs.

This manual does not cover load arrangement for loads during execution and maintenance.

The calculation rules given in this manual are only valid if the tolerances of cold formed members comply with [2] and [21].

2.2. Minimum technological dispositions of the frame

The steel profile sheet must be put on 3 supports or more with a minimal width of intermediate support of 60 mm, in steel or timber.

Steel profile sheet directly in contact with a concrete support is not allowed.

2.3. Minimum technological dispositions of the profile sheet

Profiled sheets have within the permitted tolerances a constant nominal thickness over their entire length and may have either a uniform cross section or a tapering cross section along their length.

The cross-sections of profiled sheets essentially comprise a number of plane elements joined by curved elements and its dimensions should satisfy the general requirements given in [2], section 1.5.3.

The provisions for design by calculation given in this design manual should not be applied to cross-sections outside the range of width-to-thickness ratios b/t, h/t, c/t and d/t given in Figure 2.3 below extracted from Table 5.1 of [2]:

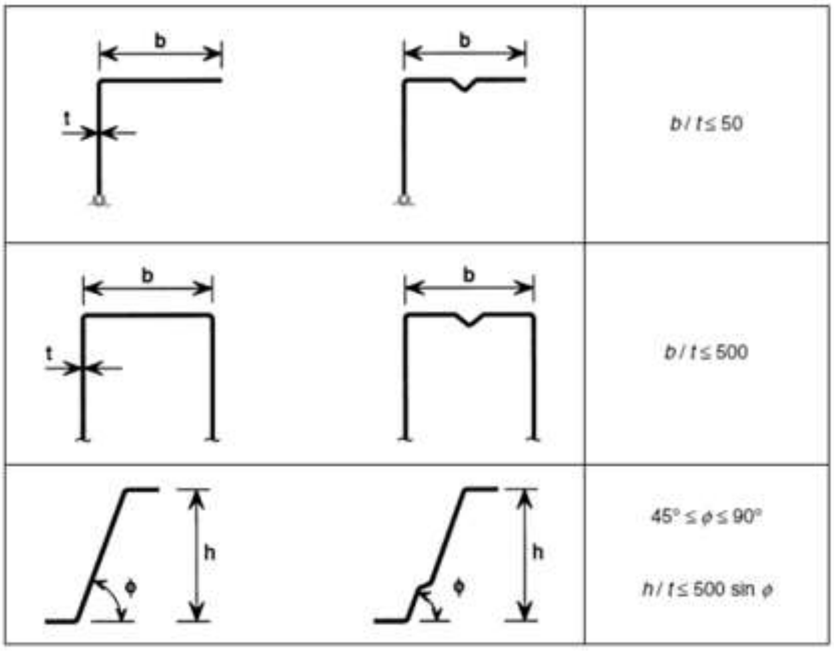


***Figure 2.3** – Range of geometrical proportions.*

The thickness, t, is a steel design thickness (the steel core thickness extracted minus tolerance if needed as specified in clause 3.2.4 of EN [2]), if not otherwise stated.

The profile sheet must present the following parameters:

- High profile with stiffeners in top flange and web,
- Minimal nominal thickness of 0,75 mm,

2.4. Minimum technological dispositions about the assemblies

Number and spacing of fasteners are those described in paragraph 2 (see figure 1.2.4).

3. BASIC TECHNOLOGICAL REQUIREMENTS

3.1. Supports

Supports comply with [18] to [20] for steel material or with [22] to [25] for timber material.

3.2. Profiles sheet and CE marking

Profile steel sheet are CE marked according to [1].

4. MATERIAL PROPERTIES

4.1. Steel sheet

The material properties should satisfy the requirements given in [2], section 3 with a minimum steel grade of S 320 GD + Z.

4.2. Fasteners

The material properties should satisfy the requirements given in [2], section 8.

4.3. Safety factors

The safety factors should satisfy the requirements given in [2], section 2.

5. ACTION LOADS AND COMBINATIONS

Action loads and combinations should be taken into account and determined according:

- [8] and [9] for basis and load combinations,
- [10] and [11] for self-weight and imposed loads,
- [12] to [14] for snow loads,
- [15] to [17] for wind loads.

6. BASIS OF THE DESIGN

6.1. Principles

This new design method is given to:

- Calculate the resistance of 4 assemblies type to combined bending moment and support reaction,
- Verify the connection between two profile steel sheets.

6.2. Field of application of the new design method

This new design method is for sheeting assembled by a statically effective overlapping, on an intermediate support, according one of the 4 joints below:

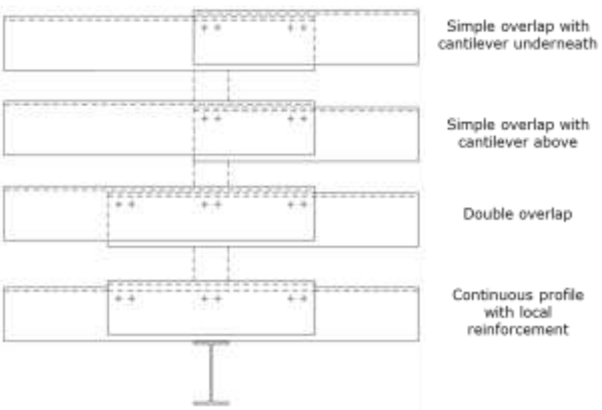


Figure 6.2.1 *– Types of assemblies covered by the new design method.*

Profile steel sheet must present the same design thickness and assembled like below:

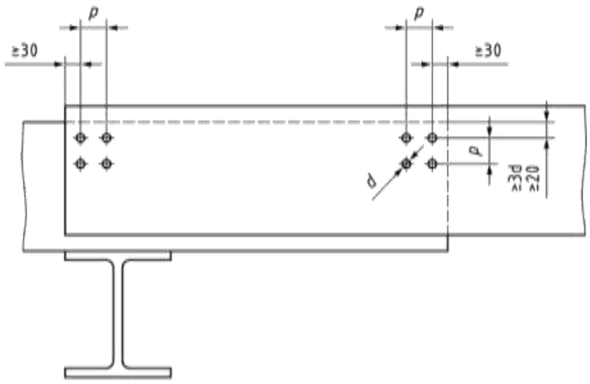


Figure 6.2.2 – Location of *fasteners according for a statically effective joint.*

A maximum of 4 fasteners, arranged in square, should be used to connect the steel sheet:

- per web,
- located at the end of the overlap and,
- located at the axis of the intermediate support.

Each group of 4 fasteners should be spaced at 30 mm minimum from the ends of overlapping and be spaced at 20 mm minimum, no lower than 3d with d the diameter of hole, from the top flange of steel sheets.
The horizontal and vertical distance between fasteners should be greater than the minimum between 4d and 40 mm.

6.3. Design procedure

6.3.1. Steel sheets assembled with single overlap joint with cantilever above

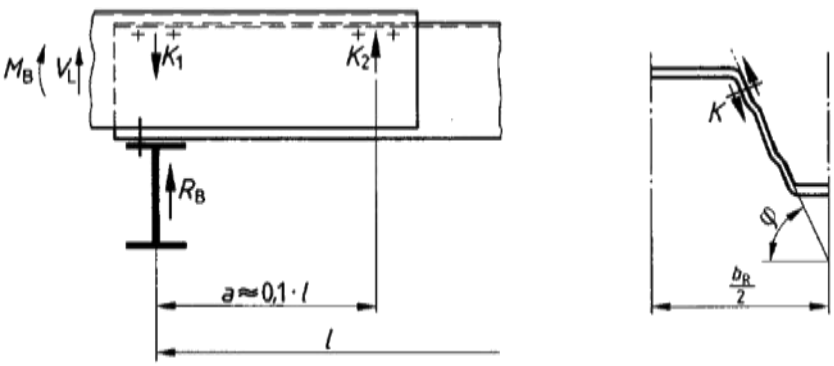


Figure 6.3.1 *– Single overlap with cantilever steel sheet above.*

<u>Verification of the resistance of the assembly</u>

The Verification of the resistance of the assembly in the support axis is conducted with the design resistance values ($M_{B,Rd}$ and $R_{w,Rd,B}$) of the continuous profile, in the same design thickness, taking into account the influence of support reaction (M-R-interaction) for downward loading and M-V interaction for uplift loading.

$M_{B,Rd}$ and $R_{w,Rd,B}$ should be determined by calculation according 6.1.4 and 6.1.7 of [2] and interactions according 6.1.11 of [2].

Verification of web crippling

For downward loading, the web crippling at the end of cantilever must be verified with:

$$F_{Ed} = M_{B,Ed}/a < 0.5 \cdot R_{w,Rd,B}$$

With: $R_{w,Rd,B}$ the ultimate support reaction at intermediate supports in the opposite profile position (in general negative position) for the maximum support width, in general $l_{a,B}$ = 160 mm.

Taking account of the normal profile position defined in Figure 1.1, the opposite profile position is the position for which the biggest flange (top flange in Figure 1.1) is in contact with the support.

For uplift loading, web crippling at the end of the cantilever is not possible. In such case of loading, no verification is needed.

Verification of the connection K_{Ed}

The verification, performed in one web, should be done with:

$$\frac{K_{Ed}}{\sum F_{V,Rd}} \leq 1{,}0$$

And:

$$K_{Ed} = \max K_i = \frac{\left|\left(M_{B,Ed}/a\right) + V_{L,Ed}\right|}{(2 \cdot \sin\varphi)} \cdot b_R$$

With: $\sum F_{V,Rd}$ the shear resistance of the screws.

6.3.2. Steel sheets assembled with single overlap joint with cantilever underneath

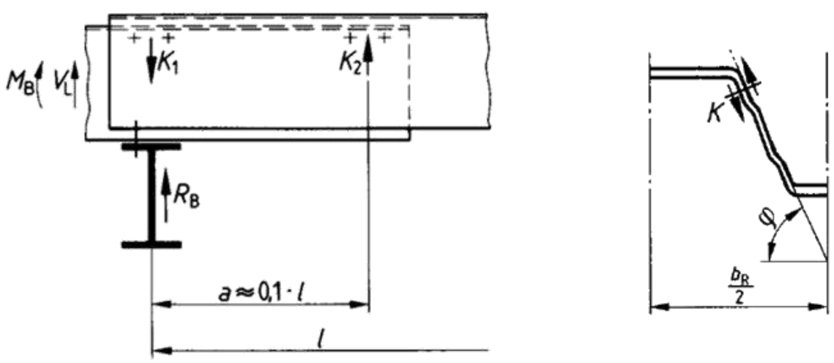


***Figure 6.3.2** – Single overlap with cantilever steel sheet underneath.*

Verification of the resistance of the assembly

The Verification of the resistance of the assembly in the support axis is conducted with the design resistance values ($M_{B,Rd}$ and $R_{w,Rd,B}$) of the continuous profile, in the same design thickness, taking into account the influence of support reaction (M-R-interaction) for downward loading and M-V interaction for uplift loading.

$M_{B,Rd}$ and $R_{w,Rd,B}$ should be determined by calculation according 6.1.4 and 6.1.7 of [2] and interactions according 6.1.11 of [2].

Verification of web crippling

For both case of loading (uplift and downward), web crippling at the end of the cantilever is not possible and no verification is needed.

Verification of the connection K_{Ed}

The verification, performed in one web, should be done with:

$$\frac{K_{Ed}}{\sum F_{V,Rd}} \leq 1{,}0$$

And:

$$K_{Ed} = \max K_i = \frac{|M_{B,Ed}|}{(2 \cdot \mathrm{a} \cdot \sin\varphi)} \cdot b_R$$

With: $\sum F_{V,Rd}$ the shear resistance of the screws.

6.3.3. Steel sheets assembled with double overlap joint

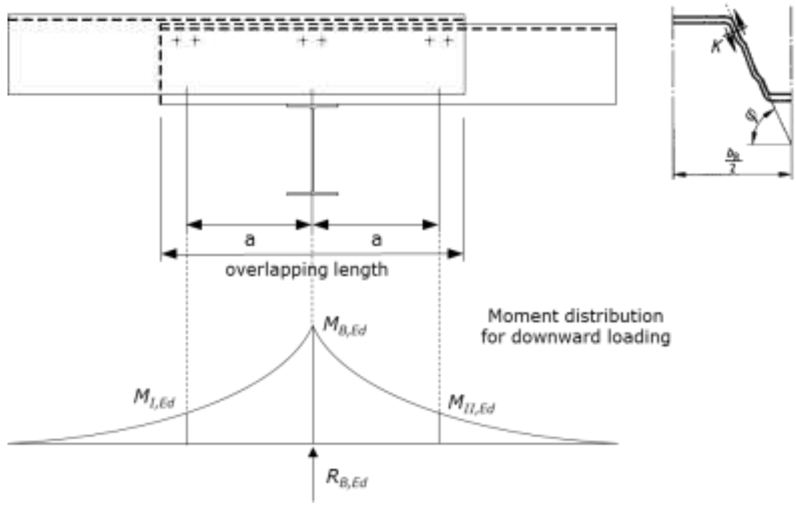


***Figure 6.3.3** – Double overlap.*

Preliminary consideration

Bending moment distribution under design loads like for continuous sheets should be determined in order to evaluate $M_{B,Ed}$, $M_{I,Ed}$, $M_{II,Ed}$ and $R_{Ed,B}$.

Verification of the resistance of the assembly at the support axis

The Verification of the resistance of the assembly in the support axis is conducted with 90 % of the design resistance values ($M_{B,Rd}$ and $R_{w,Rd,B}$) of each profile, in the same design thickness, taking into account the influence of support reaction (M-R-interaction) and M-V interaction as follow:

$$M_{B,Ed} \leq 0{,}9 \cdot \sum M_{B,Rd};$$

$$R_{B,Ed} \leq 0{,}9 \cdot \sum R_{w,Rd,B};$$

M-R or M-V interaction following 6.1.11 of [2].

Verification of the resistance of the assembly at the ends of the overlap

These verification, of the continuous profiles, is conducted with the bending moments $M_{I,Ed}$ or $M_{II,Ed}$ and the corresponding line loads introduced by the connections K_i:

$$F_{Ed} = \frac{M_{B,Ed}}{2 \cdot a}$$

The line load F_{Ed} is determined for both case of loading (downward and uplift).

For downward loading, F_{Ed} is acting as a tension force on the webs of the continuous profiles and the verification is composed as follows:

$$\frac{M_{I,Ed}}{M_{B,Rd}} \leq 1{,}0;$$

$$\frac{M_{II,Ed}}{M_{B,Rd}} \leq 1{,}0\ ;$$

$$\frac{F_{Ed}}{V_{w,Rd}} \leq 1{,}0;$$

M-V interaction following 6.1.11 of [2].

For uplift loading, F_{Ed} is acting as a compression force on the webs of the continuous profiles and the verification is composed as follows:

$$\frac{M_{I,Ed}}{M_{B,Rd}} \leq 1{,}0;$$

$$\frac{M_{II,Ed}}{M_{B,Rd}} \leq 1{,}0;$$

$$\frac{F_{Ed}}{R_{w,Rd,B}} \leq 1{,}0;$$

M-R interaction following 6.1.11 of [2].

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

Verification of web crippling

For downward loading, the web crippling at the end of cantilever must be verified with:

$$F_{Ed} = M_{B,Ed}/(2 \cdot a) < 0.5 \cdot R_{w,Rd,B}$$

With: $R_{w,Rd,B}$ the ultimate support reaction at intermediate supports in the opposite profile position (in general negative position) for the maximum support width, in general $l_{a,B}$ = 160 mm.

Taking account of the normal profile position defined in Figure 1.1, the opposite profile position is the position for which the biggest flange (top flange in Figure 1.1) is in contact with the support.

For uplift loading, web crippling at the end of the cantilever is not possible. In such case of loading, no verification is needed.

Verification of the connection K_{Ed}

The verification, performed in one web, should be done with:

$$\frac{K_{Ed}}{\sum F_{V,Rd}} \leq 1{,}0$$

And:

$$K_{Ed} = \max K_i = \frac{|M_{B,Ed}|}{(4 \cdot \mathrm{a} \cdot \sin \varphi)} \cdot b_R$$

With: $\sum F_{V,Rd}$ the shear resistance of the screws.

The verification of the connection must be performed for both cases of loading (downward and uplift).

6.3.4. Continuous profile with local reinforcement

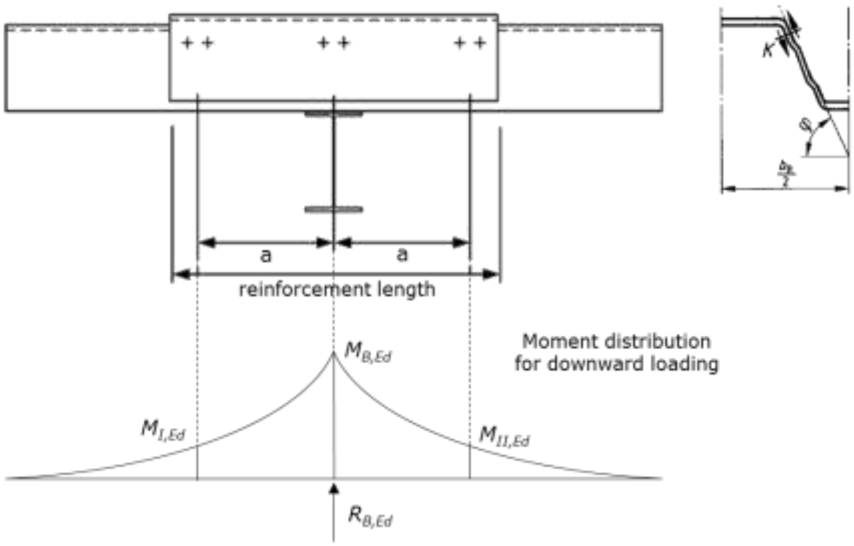


Figure 6.3.4 – *Continuous profile with local reinforcement.*

Preliminary consideration

Bending moment distribution under design loads like for continuous sheets should be determined in order to evaluate $M_{B,Ed}$, $M_{I,Ed}$, $M_{II,Ed}$ and $R_{Ed,B}$.

Verification of the resistance of the assembly at the support axis

The Verification of the resistance of the assembly in the support axis is conducted with 90 % of the design resistance values ($M_{B,Rd}$ and $R_{w,Rd,B}$) of each profile, in the same design thickness, taking into account the influence of support reaction (M-R-interaction) and M-V interaction as follow:

$$M_{B,Ed} \leq 0{,}9 \cdot \sum M_{B,Rd};$$

$$R_{B,Ed} \leq 0{,}9 \cdot \sum R_{w,Rd,B};$$

M-R or M-V interaction following 6.1.11 of [2].

Verification of the resistance of the assembly at the ends of the overlap

These verification, of the continuous profiles, is conducted with the bending moments $M_{I,Ed}$ or $M_{II,Ed}$ and the corresponding line loads introduced by the connections K_i:

$$F_{Ed} = \frac{M_{B,Ed}}{2 \cdot a}$$

The line load F_{Ed} is determined for both case of loading (downward and uplift).

For downward loading, F_{Ed} is acting as a tension force on the webs of the continuous profiles and the verification is composed as follows:

$$\frac{M_{I,Ed}}{M_{B,Rd}} \leq 1{,}0;$$

$$\frac{M_{II,Ed}}{M_{B,Rd}} \leq 1{,}0\ ;$$

$$\frac{F_{Ed}}{V_{w,Rd}} \leq 1{,}0;$$

M-V interaction following 6.1.11 of [2].

For uplift loading, F_{Ed} is acting as a compression force on the webs of the continuous profiles and the verification is composed as follows:

$$\frac{M_{I,Ed}}{M_{B,Rd}} \leq 1{,}0;$$

$$\frac{M_{II,Ed}}{M_{B,Rd}} \leq 1{,}0;$$

$$\frac{F_{Ed}}{R_{w,Rd,B}} \leq 1{,}0;$$

M-R interaction following 6.1.11 of [2].

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

Verification of web crippling

For downward loading, the web crippling at the end of cantilever must be verified with:

$$F_{Ed} = M_{B,Ed}/(2 \cdot a) < 0.5 \cdot R_{w,Rd,B}$$

With: $R_{w,Rd,B}$ the ultimate support reaction at intermediate supports in the opposite profile position (in general negative position) for the maximum support width, in general $l_{a,B}$ = 160 mm.

Taking account of the normal profile position defined in Figure 1.1, the opposite profile position is the position for which the biggest flange (top flange in Figure 1.1) is in contact with the support.

For uplift loading, web crippling at the end of the cantilever is not possible. In such case of loading, no verification is needed.

Verification of the connection K_{Ed}

The verification, performed in one web, should be done with:

$$\frac{K_{Ed}}{\sum F_{V,Rd}} \leq 1{,}0$$

And:

$$K_{Ed} = \max K_i = \frac{|M_{B,Ed}|}{(4 \cdot \mathrm{a} \cdot \sin \varphi)} \cdot b_R$$

With: $\sum F_{V,Rd}$ the shear resistance of the screws.

The verification of the connection must be performed for both cases of loading (downward and uplift).

7. SPECIFIC DESIGN CONSIDERATION

The subsequent issues are not covered by the present design manual:

- For fire: it should be considered national regulations in agreement with EN 1991-1-2 and EN 1993-1-2;
- For seismic: it should be considered national regulations in agreement with EN 1998-1;
- For environmental aspect: it should be considered national regulations;
- For thermal: it should be considered national regulations in agreement with EN 1991-1-5;
- For acoustic: it should be considered national regulations.

And for all other subject not clearly identified higher or lower.

8. DESIGN EXAMPLES

8.1. Description of frame and loading assumption

These design example deals with a flat roof application of two buildings for which the steel frame is composed of IPE 330 beam (160 mm width) with current span of 5,45 m and a verification of assemblies located in areas H and I according 7.2.3 of EN 1991-1-4.

Both flat roofs are composed by a profile steel sheet, a mineral wool insulation and a ceiling. The total self-weight of insulation and ceiling g_1 is 0,25 kN/m² for building 1 case and 1,00 kN/m² for building 2 case (presence of heavy protection).

8.1.1. Information for building 1

The first building of 16 m height, building 1, is located in an industrial area near Oostende (Belgium) with parapet of 80 cm all around the flat roof.

The fundamental value of the basic wind velocity $v_{b,0}$ is 26 m.s^{-1}.

Terrain category is assumed to be 0.

Directional factor c_{dir} and season factor c_{season} are fixed to 1. Orography factor $c_0(z)$ is taken to 1.

The recommended value of 1 is considered for the turbulence factor k_I.

For the air density ρ, the recommended value is applied: ρ = 1,25 kg/m^3.

Location of the building in a windswept topography: C_e = 0,8 according [12].

Snow load shape coefficient μ_i of 0,8.

8.1.2. Loading assumption for building 1

This design example doesn't deal with mounting phase. In service phase, loads are provided by wind effects and dead loads.

Snow loads are neglected due to characteristic value of snow load on the ground s_k at sea level of 0,2 kN/m² according [12] and a combination factor Ψ_0 of 0,5 according the Belgium national annex of [12] ($s = \mu_i \cdot C_e \cdot C_t \cdot s_k$ = 0,064 daN/m² for the exact application).

Determination of wind action according [15] to [17]

Basic wind velocity $v_b = c_{dir} \cdot c_{season} \cdot v_{b,0} = 1{,}00 \cdot 1{,}00 \cdot 26 = 26$ m.s^{-1}.

Mean wind $v_m(z)$:

- Terrain category 0: $z_0 = 0{,}003$ m and $z_{min} = 1$ m;
- $z_{0,II} = 0{,}05$ m;
- Terrain factor $k_r = 0{,}19 \cdot \left(\frac{z_0}{z_{0,II}}\right)^{0{,}07} = 0{,}19 \cdot \left(\frac{0{,}003}{0{,}05}\right)^{0{,}07} \approx 0{,}156$;
- Roughness factor $c_r(z) = k_r \cdot ln\left(\frac{z}{z_0}\right) = 0{,}156 \cdot ln\left(\frac{16}{0{,}003}\right) \approx 1{,}339$;
- $v_m(z) = c_r(z) \cdot c_0(z) \cdot v_b = 1{,}339 \cdot 1{,}00 \cdot 26 \approx 34{,}8\, m.s^{-1}$;

Wind turbulence $I_v(z) = \frac{k_l}{c_0(z) \cdot ln(z/z_0)} = \frac{1{,}00}{1{,}00 \cdot ln(16/0{,}003)} \approx 0{,}117$

Peak velocity pressure $q_p(z) = [1 + 7 \cdot I_v(z)] \cdot \frac{1}{2} \cdot \rho \cdot v_m^2(z) = [1 + 7 \cdot 0{,}117] \cdot \frac{1}{2} \cdot 1{,}25 \cdot 34{,}8^2 \approx 1{,}38\, kN/m^2$

Pressure coefficients for flat roof:

- $h_p/h = 0{,}8/16 = 0{,}05$;
- External pressure coefficients $c_{pe,10}$:
    - Zone H: -0,7
    - Zone I: +0,2/-0,2
- Internal pressure coefficient c_{pi} = +0,2/-0,3
- Global coefficient $c_{p,net}$:
    - For wind pressure effect: $c_{p,net}$ = 0,5
    - For wind suction effect: $c_{p,net}$ = -0,9

Wind loads W_{50}:

- For pressure effect: W_{50}^+ = 0,69 kN/m²
- For suction effect: W_{50}^- = - 1,24 kN/m²

Loads combination according [8], [9] and Belgium national annex of [8]

The most severe combination in pressure effect is: $Q^+ = 1{,}50 \cdot W_{50}^+ + 1{,}35 \cdot (g_0 + g_1) = 1{,}50 \cdot 0{,}69 + 1{,}35 \cdot (0{,}097 + 0{,}25) \approx 1{,}50$ kN/m²

The most severe combination in suction effect is: $Q^- = 1{,}50 \cdot W_{50}^- + (g_0 + g_1) = 1{,}50 \cdot (-1{,}24) + (0{,}097 + 0{,}25) \approx -1{,}51$ kN/m²

For g_0 see paragraph 8.2 and for g_1 see paragraph 8.1.1.

8.1.3. Information for building 2

Building 2 is the same than building 1. See paragraph 8.1.1 to consult information.

8.1.4. Loading assumption for building 2

For building 2 the flat roof device is different due to self-weight on insulation coupled to heavy protection (g_1 = 1,00 kN/m²).

For snow load consideration and determination of wind effect: see paragraph 8.1.4.

Loads combination according [8], [9] and Belgium national annex of [8]

The most severe combination in pressure effect is: $Q^+ = 1{,}50 \cdot W_{50}^+ + 1{,}35 \cdot (g_0 + g_1) = 1{,}50 \cdot 0{,}69 + 1{,}35 \cdot (0{,}097 + 1{,}00) \approx 2{,}51$ kN/m²

The most severe combination in suction effect is: $Q^- = 1{,}50 \cdot W_{50}^- + (g_0 + g_1) = 1{,}50 \cdot (-1{,}24) + (0{,}097 + 1{,}00) \approx -0{,}76$ kN/m²

For g_0 see paragraph 8.2.

8.2. Description of profile steel sheeting

The profile steel sheet is a 137-310-930 trapezoidal geometry as follows:

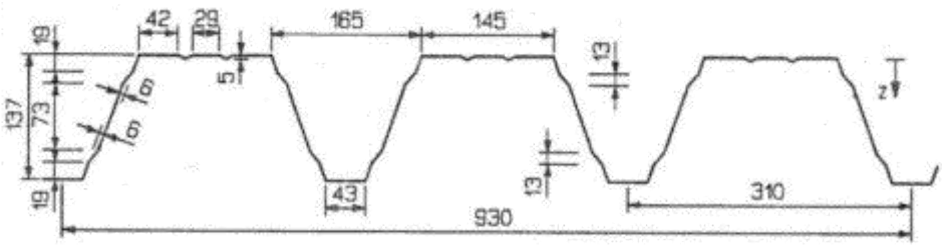


***Figure 8.2** – 137-310-930 trapezoidal steel sheet in positive.*

Pitch of the profile, b_r, is 310 mm. Web angle $\varphi = 66°$.

The profile is in steel grade S 320 GD + Z 275 in 0,75 mm nominal thickness. Self-weight g_0 of profile is 0,097 kN/m².

The design resistance values of these profile are determined by calculation according [2] and considering a safety factor γ_m of 1,10:

- Bending design resistance on support for normal profile position under downward loading:

$$M_{b,Rd} = 8{,}17/1{,}1 = 7{,}42 \text{ [kNm/m]}$$

- Bending design resistance on support and at the end of the overlap for opposite profile position under downward loading:

$$M_{b,Rd} = 9{,}66/1{,}1 = 8{,}78 \text{ [kNm/m]}$$

- Bending design resistance on support for normal profile position under uplift loading:

$$M_{b,Rd} = 9{,}66/1{,}1 = 8{,}78 \text{ [kNm/m]}$$

- Bending design resistance on support for opposite profile position under uplift loading:

$$M_{b,Rd} = 8{,}30/1{,}1 = 7{,}54 \text{ [kNm/m]}$$

- Design resistance to intermediate support reaction (160 mm width of support):

$$R_{w,Rd,B} = 22{,}82/1{,}1 = 20{,}74 \text{ [kN/m]}$$

- Design resistance to intermediate support reaction for opposite profile position (160 mm width of support):

$$R_{w,Rd,B,la=160} = 22{,}89/1{,}1 = 20{,}80 \text{ [kN/m]}$$

- Shear design resistance:

$$V_{w,Rd} = 28{,}49/1{,}1 = 25{,}9 \text{ [kN/m]}$$

8.3. Description of fasteners and assemblies

Fasteners comply [2] section 8 and are 6.3 mm diameter screws for which shear design resistance values are in the scope of an ETA.

The shear design resistance of each screw, considering two steel thickness of 0,75 mm, is $F_{v,Rd} =$ 0,875 kN and consequently: $\sum F_{v,Rd} = 3{,}50$ kN.

Each group of 4 screws are spaced of 30 mm from end of overlap and top flange of profile; and the distance between screws is 30 mm.

Flat roofing of building 1 is realized with steel sheets assembled with single overlap joints with alternatively cantilever above and underneath. The overlap length (a) is 0,80 m.

Flat roofing of building 2 is divided on 2 areas: one realized with steel sheets assembled with double overlap joint and one realized with continuous profiles with local reinforcement. The overlap length is the same than the reinforcement length: a = 0,80 m.

8.4. Verification of assemblies for building 1

8.4.1. Loading application

It's considering 2 equal spans, L, system of 5m45 under uniform distributed loading.

For wind pressure effect, the application of load combination, see paragraph 8.1.2, drives to:

- An applied moment on intermediate support $M_{B,Ed} = (Q^+ \cdot L^2)/8 = (1{,}5 \cdot 5{,}45^2)/8 = 5{,}57$ kNm/m;
- A reaction on intermediate support of: $R_{B,Ed} = 1{,}25 \cdot Q^+ \cdot L = 1{,}25 \cdot 1{,}5 \cdot 5{,}45 = 10{,}22$ kN/m;
- A maximum shear load of: $V_{L,Ed} = (5 \cdot Q^+ \cdot L)/8 = (5 \cdot 1{,}5 \cdot 5{,}45)/8 = 5{,}11$ kN/m.

For wind suction effect, the application of load combination, see paragraph 8.1.2, drives to:

- An applied moment on intermediate support $M_{B,Ed} = (Q^- \cdot L^2)/8 = (1{,}51 \cdot 5{,}45^2)/8 = 5{,}61$ kNm/m;
- A reaction on intermediate support of: $R_{B,Ed} = 1{,}25 \cdot Q^- \cdot L = 1{,}25 \cdot 1{,}51 \cdot 5{,}45 = 10{,}29$ kN/m;
- A maximum shear load of: $V_{L,Ed} = (5 \cdot Q^- \cdot L)/8 = (5 \cdot 1{,}51 \cdot 5{,}45)/8 = 5{,}14$ kN/m.

8.4.2. Steel sheets assembled with single overlap joint with cantilever above

Verification of the resistance of the assembly

Under downward loading:

- Moment on intermediate support: $\frac{M_{B,Ed}}{M_{B,Rd}} = \frac{5,57}{7,42} = 0.751 < 1,0;$
- Resistance on the support: $\frac{R_{B,Ed}}{R_{w,Rd,B}} = \frac{10,22}{20,74} = 0.493 < 1,0;$
- Interaction between moment and support reaction: $\frac{M_{B,Ed}}{M_{B,Ed}} + \frac{R_{B,Ed}}{R_{w,Rd,B}} = 0,751 + 0,493 = 1,244 < 1,25.$

For uplift loading:

- Moment on intermediate support: $\frac{M_{B,Ed}}{M_{B,Rd}} = \frac{5,61}{8,78} = 0.638 < 1,0;$
- Resistance on the support: $\frac{V_{L,Ed}}{V_{w,Rd}} = \frac{5,14}{25,90} = 0.199 < 1,0;$
- Interaction between moment and support reaction: $\frac{M_{B,Ed}}{M_{B,Ed}} + \frac{V_{L,Ed}}{V_{w,Rd}} = 0,638 + 0,199 = 0,837 < 1,25.$

In addition, verification of fasteners must be performed according [2].

Verification of web crippling

For downward loading: $\frac{M_{B,Ed}}{(a \cdot 0,5 \cdot R_{w,Rd,B,la=160})} = \frac{5,57}{(0,8 \cdot 0,5 \cdot 20,80)} = 0,670 < 1,0.$

For uplift loading, verification of web crippling is not relevant.

Verification of the connection K_{Ed}:

$$K_{Ed} = \frac{|(5,57/0,8)+5,11|}{(2 \cdot \sin(66°))} \cdot 0,31 = 2,05 \text{ kN}$$

$$\frac{K_{Ed}}{\sum F_{V,Rd}} = \frac{2,05}{3,50} = 0,585 < 1,0$$

8.4.3. Steel sheets assembled with single overlap joint with cantilever underneath

Verification of the resistance of the assembly

Under downward loading:

- Moment on intermediate support: $\frac{M_{B,Ed}}{M_{B,Rd}} = \frac{5,57}{7,42} = 0.751 \ < 1,0;$

- Resistance on the support: $\frac{R_{B,Ed}}{R_{w,Rd,B}} = \frac{10,22}{20,74} = 0.493 < 1,0;$

- Interaction between moment and support reaction: $\frac{M_{B,Ed}}{M_{B,Ed}} + \frac{R_{B,Ed}}{R_{w,Rd,B}} = 0,751 + 0,493 = 1,244 \ < 1,25.$

For uplift loading:

- Moment on intermediate support: $\frac{M_{B,Ed}}{M_{B,Rd}} = \frac{5,61}{8,78} = 0.638 < 1,0;$

- Shear resistance: $\frac{V_{L,Ed}}{V_{w,Rd}} = \frac{5,14}{25,90} = 0.199 < 1,0;$

- Interaction between moment and shear: $\frac{M_{B,Ed}}{M_{B,Ed}} + \frac{V_{L,Ed}}{V_{w,Rd}} = 0,638 + 0,199 = 0,837 \ < 1,25.$

In addition, verification of fasteners must be performed according [2].

Verification of web crippling

For both case of loading, no verification is needed.

Verification of the connection K_{Ed}:

$$K_{Ed} = \frac{|5,57|}{(2 \cdot 0,8 \cdot \sin(66°))} \cdot 0,31 = 1,18 \text{ kN}$$

$$\frac{K_{Ed}}{\sum F_{V,Rd}} = \frac{1,18}{3,50} = 0.338 < 1,0$$

8.5. Verification of assemblies for building 2

8.5.1. Profile steel sheeting

The profile steel sheet is a 137-310-930 trapezoidal geometry as defined at paragraph 8.2.

Pitch of the profile, b_r, is 310 mm. Web angle $\varphi = 66°$.

The profile is in steel grade S 320 GD + Z 275 in 0,75 mm nominal thickness. Self-weight g_0 of profile is 0,097 kN/m².

The design resistance values of these profile are:

- Bending design resistance on support for normal profile position under downward loading:

$$M_{b,Rd} = 7,42 \text{ [kNm/m]}$$

- Bending design resistance on support and at the end of the overlap for opposite profile position under downward loading:

$$M_{b,Rd} = 8{,}78 \text{ [kNm/m]}$$

- Bending design resistance on support for normal profile position under uplift loading:

$$M_{b,Rd} = 8{,}78 \text{ [kNm/m]}$$

- Bending design resistance on support for opposite profile position under uplift loading:

$$M_{b,Rd} = 7{,}54 \text{ [kNm/m]}$$

- Design resistance to intermediate support reaction (160 mm width of support):

$$R_{w,Rd,B} = 20{,}74 \text{ [kN/m]}$$

- Design resistance to intermediate support reaction for opposite profile position (160 mm width of support):

$$R_{w,Rd,B,la=160} = 20{,}80 \text{ [kN/m]}$$

- Shear design resistance:

$$V_{w,Rd} = 25{,}9 \text{ [kN/m]}$$

8.5.2. Loading application

It's considering 2 equal spans, L, system of 5m45 under uniform distributed loading.

For wind pressure effect, the application of load combination, see paragraph 8.1.4, drives to:

- An applied moment on intermediate support $M_{B,Ed} = (Q^+ \cdot L^2)/8 = (2{,}51 \cdot 5{,}45^2)/8 = 9{,}33$ kNm/m;

- A reaction on intermediate support of: $R_{B,Ed} = 1{,}25 \cdot Q^+ \cdot L = 1{,}25 \cdot 2{,}51 \cdot 5{,}45 = 17{,}12$ kN/m;

- A maximum shear load of: $V_{L,Ed} = (5 \cdot Q^+ \cdot L)/8 = (5 \cdot 2{,}51 \cdot 5{,}45)/8 = 8{,}56$ kN/m;

- A moment at the end of overlap of 3,29 kNm/m ($M_{I,Ed}$=$M_{II,Ed}$) as defined in Figure 8.5.2 below:

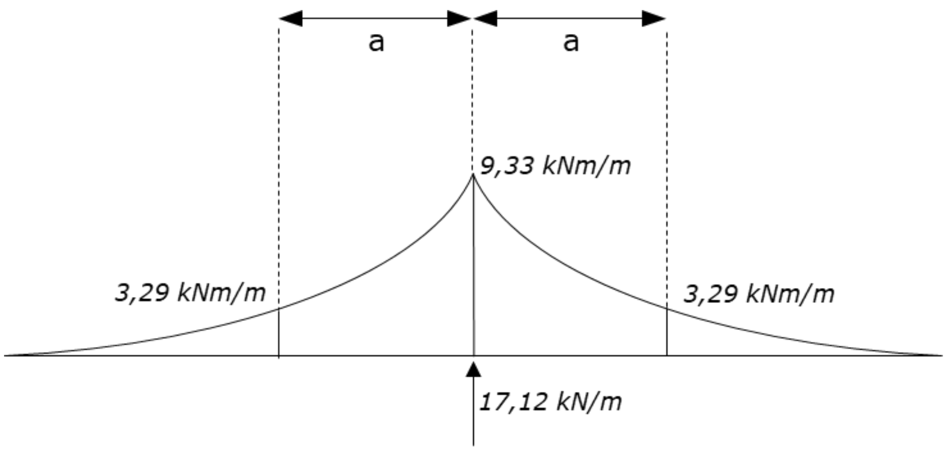


__Figure 8.5.2a__ – Moment distribution for downward loading.

For wind suction effect, the application of load combination, see paragraph 8.1.4, drives to:

- An applied moment on intermediate support $M_{B,Ed} = (Q^{-} \cdot L^2)/8 = (0{,}76 \cdot 5{,}45^2)/8 = 2{,}82$ kNm/m;
- A reaction on intermediate support of: $R_{B,Ed} = 1{,}25 \cdot Q^{-} \cdot L = 1{,}25 \cdot 0{,}76 \cdot 5{,}45 = 5{,}18$ kN/m;
- A maximum shear load of: $V_{L,Ed} = (5 \cdot Q^{-} \cdot L)/8 = (5 \cdot 0{,}76 \cdot 5{,}45)/8 = 2{,}59$ kN/m;
- A moment at the end of overlap of 0,99 kNm/m ($M_{I,Ed}$=$M_{II,Ed}$) as defined in Figure 8.5.2b below:

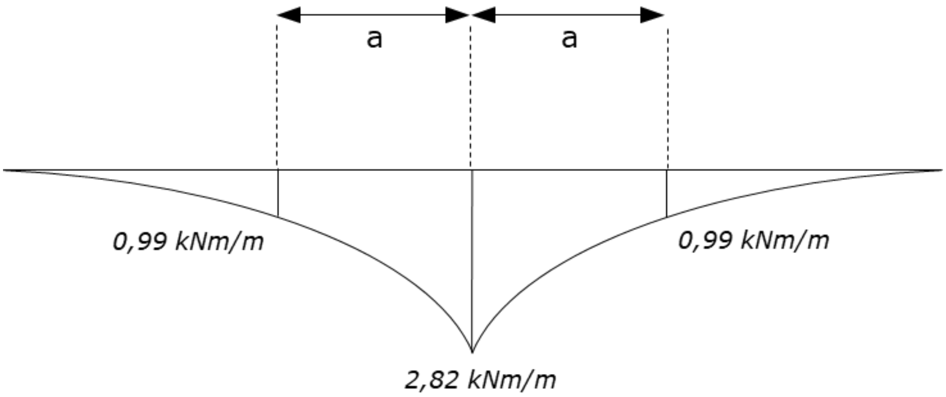


__Figure 8.5.2a__ – Moment distribution for uplift loading.

8.5.3. Steel sheets assembled with double overlap joint

<u>Verification of the resistance of the assembly at the support axis</u>

Under downward loading:

- Moment on intermediate support: $\frac{M_{B,Ed}}{0{,}9 \cdot \sum M_{B,Rd}} = \frac{9{,}33}{0{,}9 \cdot 2 \cdot 7{,}42} = 0{,}699 < 1{,}0$;
- Resistance on the support: $\frac{R_{B,Ed}}{0{,}9 \cdot \sum R_{w,Rd,B}} = \frac{17{,}12}{0{,}9 \cdot 2 \cdot 20{,}74} = 0{,}459 < 1{,}0$;
- Interaction between moment and support reaction: $\frac{M_{B,Ed}}{0{,}9 \cdot \sum M_{B,Rd}} + \frac{R_{B,Ed}}{0{,}9 \cdot \sum R_{w,Rd,B}} = 0{,}699 + 0{,}459 = 1{,}158 < 1{,}25$.

For uplift loading:

- Moment on intermediate support: $\frac{M_{B,Ed}}{0{,}9 \cdot \sum M_{B,Rd}} = \frac{2{,}82}{0{,}9 \cdot 2 \cdot 8{,}78} = 0{,}178 < 1{,}0$;
- Shear resistance: $\frac{V_{L,Ed}}{0{,}9 \cdot \sum V_{w,Rd}} = \frac{2{,}59}{0{,}9 \cdot 2 \cdot 25{,}90} = 0{,}056 < 1{,}0$;

- Interaction between moment and shear: $\frac{M_{B,Ed}}{0{,}9 \cdot \sum M_{B,Rd}} + \frac{V_{L,Ed}}{0{,}9 \cdot \sum V_{w,Rd}} = 0{,}178 + 0{,}056 = 0{,}234 < 1{,}25$.

Verification of the resistance of the assembly at the ends of the overlap

For downward loading, the verification is composed as follows:

$$\text{Line load } F_{Ed} = \frac{M_{B,Ed}}{2 \cdot a} = \frac{9{,}33}{2 \cdot 0{,}8} = 5{,}83 \text{ kN/m}$$

$$\frac{M_{I,Ed}}{M_{B,Rd}} = \frac{M_{II,Ed}}{M_{B,Rd}} = \frac{3{,}29}{7{,}54} = 0{,}436 \leq 1{,}0;$$

$$\frac{F_{Ed}}{V_{w,Rd}} = \frac{5{,}83}{25{,}90} = 0{,}225 \leq 1{,}0;$$

$$\frac{M_{I,Ed}}{M_{B,Rd}} + \frac{F_{Ed}}{V_{w,Rd}} = 0{,}374 + 0{,}225 = 0{,}599 < 1{,}25.$$

For uplift loading, the verification is composed as follows:

$$\text{Line load } F_{Ed} = \frac{M_{B,Ed}}{2 \cdot a} = \frac{2{,}82}{2 \cdot 0{,}8} = 1{,}76 \text{ kN/m}$$

$$\frac{M_{I,Ed}}{M_{B,Rd}} = \frac{M_{II,Ed}}{M_{B,Ed}} = \frac{0{,}99}{8{,}78} = 0{,}113 \leq 1{,}0;$$

$$\frac{F_{Ed}}{R_{w,Rd,B}} = \frac{1{,}76}{20{,}80} = 0{,}085 \leq 1{,}0;$$

$$\frac{M_{I,Ed}}{M_{B,Rd}} + \frac{F_{Ed}}{R_{w,Rd,B}} = 0{,}113 + 0{,}085 = 0{,}198 \leq 1{,}25.$$

Verification of web crippling

For downward loading:

$$\frac{M_{B,Ed}}{\left(2 \cdot a \cdot 0{,}5 \cdot R_{w,Rd,B,la=160}\right)} = \frac{9{,}33}{(2 \cdot 0{,}8 \cdot 0{,}5 \cdot 20{,}80)} = 0{,}561 < 1{,}0$$

For uplift loading, verification of web crippling is not relevant.

Verification of the connection K_{Ed}

For downward loading:

$$K_{Ed} = \frac{9{,}33}{(4 \cdot 0{,}8 \cdot \sin(66))} \cdot 0{,}31 = 0{,}99 \text{ kN}$$

And:

$$\frac{K_{Ed}}{\sum F_{V,Rd}} = \frac{0{,}99}{3{,}50} = 0{,}283 \leq 1{,}0$$

For uplift loading:

$$K_{Ed} = \frac{2{,}82}{(4 \cdot 0{,}8 \cdot \sin(66))} \cdot 0{,}31 = 0{,}30 \text{ kN}$$

And:

$$\frac{K_{Ed}}{\sum F_{V,Rd}} = \frac{0{,}30}{3{,}50} = 0{,}085 \leq 1{,}0$$

8.5.4. Continuous profile with local reinforcement

Verification of the resistance of the assembly at the support axis

Under downward loading:

- Moment on intermediate support: $\frac{M_{B,Ed}}{0{,}9 \cdot \sum M_{B,Rd}} = \frac{9{,}33}{0{,}9 \cdot 2 \cdot 7{,}42} = 0{,}699 < 1{,}0;$
- Resistance on the support: $\frac{R_{B,Ed}}{0{,}9 \cdot \sum R_{w,Rd,B}} = \frac{17{,}12}{0{,}9 \cdot 2 \cdot 20{,}74} = 0{,}459 < 1{,}0;$
- Interaction between moment and support reaction: $\frac{M_{B,Ed}}{0{,}9 \cdot \sum M_{B,Rd}} + \frac{R_{B,Ed}}{0{,}9 \cdot \sum R_{w,Rd,B}} = 0{,}699 + 0{,}459 = 1{,}158 < 1{,}25.$

For uplift loading:

- Moment on intermediate support: $\frac{M_{B,Ed}}{0{,}9 \cdot \sum M_{B,Rd}} = \frac{2{,}82}{0{,}9 \cdot 2 \cdot 8{,}78} = 0{,}178 < 1{,}0;$
- Shear resistance: $\frac{V_{L,Ed}}{0{,}9 \cdot \sum V_{w,Rd}} = \frac{2{,}59}{0{,}9 \cdot 2 \cdot 25{,}90} = 0{,}056 < 1{,}0;$
- Interaction between moment and shear: $\frac{M_{B,Ed}}{0{,}9 \cdot \sum M_{B,Rd}} + \frac{V_{L,Ed}}{0{,}9 \cdot \sum V_{w,Rd}} = 0{,}178 + 0{,}056 = 0{,}234 < 1{,}25.$

Verification of the resistance of the continuous profile at the ends of the overlap

For downward loading, the verification is composed as follows:

$$\text{Line load } F_{Ed} = \frac{M_{B,Ed}}{2 \cdot a} = \frac{9{,}33}{2 \cdot 0{,}8} = 5{,}83 \text{ kN}$$

$$\frac{M_{I,Ed}}{M_{B,Rd}} = \frac{M_{II,Ed}}{M_{B,Rd}} = \frac{3{,}29}{7{,}54} = 0{,}436 \leq 1{,}0;$$

$$\frac{F_{Ed}}{V_{w,Rd}} = \frac{5{,}83}{25{,}90} = 0{,}225 \leq 1{,}0;$$

$$\frac{M_{I,Ed}}{M_{B,Rd}} + \frac{F_{Ed}}{V_{w,Rd}} = 0{,}436 + 0{,}225 = 0{,}661 < 1{,}25.$$

For uplift loading, the verification is composed as follows:

$$\text{Line load } F_{Ed} = \frac{M_{B,Ed}}{2 \cdot a} = \frac{2{,}82}{2 \cdot 0{,}8} = 1{,}76 \text{ kN/m}$$

$$\frac{M_{I,Ed}}{M_{B,Rd}} = \frac{M_{II,Ed}}{M_{B,Ed}} = \frac{0{,}99}{8{,}78} = 0{,}113 \leq 1{,}0;$$

$$\frac{F_{Ed}}{R_{w,Rd,B}} = \frac{1{,}76}{20{,}80} = 0{,}085 \leq 1{,}0;$$

$$\frac{M_{I,Ed}}{M_{B,Rd}} + \frac{F_{Ed}}{R_{w,Rd,B}} = 0{,}113 + 0{,}085 = 0{,}198 \leq 1{,}25.$$

<u>Verification of web crippling</u>

For downward loading:

$$\frac{M_{B,Ed}}{\left(2 \cdot a \cdot 0{,}5 \cdot R_{w,Rd,B,la=160}\right)} = \frac{9{,}33}{(2 \cdot 0{,}8 \cdot 0{,}5 \cdot 20{,}80)} = 0{,}561 < 1{,}0$$

For uplift loading, verification of web crippling is not relevant.

<u>Verification of the connection</u> K_{Ed}

For downward loading:

$$K_{Ed} = \frac{9{,}33}{(4 \cdot 0{,}8 \cdot \sin(66))} \cdot 0{,}31 = 0{,}99 \text{ kN}$$

And:

$$\frac{K_{Ed}}{\sum F_{V,Rd}} = \frac{0{,}99}{3{,}50} = 0{,}283 \leq 1{,}0$$

For uplift loading:

$$K_{Ed} = \frac{2{,}82}{(4 \cdot 0{,}8 \cdot \sin(66))} \cdot 0{,}31 = 0{,}30 \text{ kN}$$

And:

$$\frac{K_{Ed}}{\sum F_{V,Rd}} = \frac{0{,}30}{3{,}50} = 0{,}085 \leq 1{,}0$$

8.6. Software verification

8.6.1. Software information

An Excel software is available on GRISPE plus website (www.grispeplus.eu).

8.6.2. Validation of first case with building 1

For the building 1, the first and second tab of the Excel software are used.

First input data are the characteristics values of the profile, the considered safety factor γ_M and the total shear resistance value of fasteners (in web). They are implemented according Figure 8.6.2a and 8.6.2b:

- Characteristic bending resistance on support for normal profile position under downward loading: $M_{c,Rk,B} = M_{b,Rd} = 8{,}17$ [kNm/m];

- Characteristic resistance to intermediate support reaction (160 mm width of support): $R_{w,Rk,B} = R_{w,Rd,B} = 22{,}82$ [kN/m];
- Characteristic resistance to intermediate support reaction for opposite profile position (160 mm width of support): $R_{w,Rk,B,laB=160} = R_{w,Rd,B,la=160} = 22{,}89$ [kN/m];
- Shear characteristic resistance: $V_{w,Rk} = V_{w,Rd} = 28{,}49$ [kN/m];
- Safety factor γ_m of 1,10;
- Total shear resistance of fasteners: $\sum F_{V,Rd} = 3{,}50$ kN.

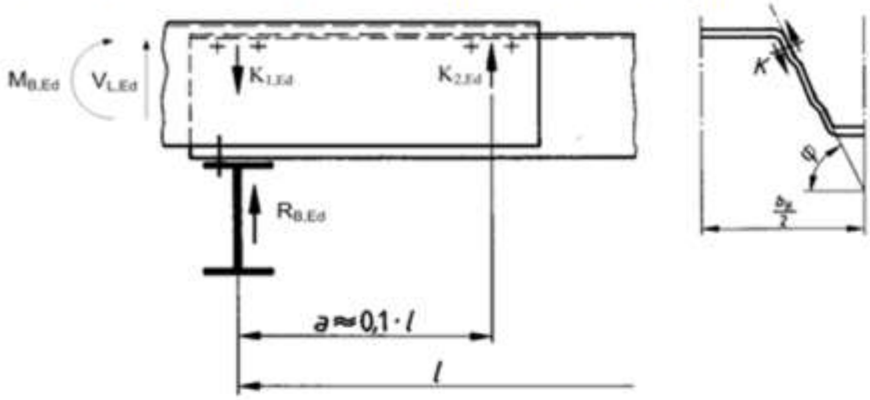
Second input data are the application of load combination, see paragraph 8.1.2 as follow:

- For downward loading:
  - Moment on intermediate support $M_{B,Ed} = 5{,}57$ kNm/m;
  - Reaction on intermediate support of: $R_{B,Ed} = 10{,}22$ kN/m;
- For uplift loading: shear load of $V_{L,Ed} = 5{,}14$ kN/m;
- Pitch of the profile: b_R = 0,31 m;
- Overlap length: a = 0,80 m;
- Web angle: φ = 66°.

Please fill in the red cells

Verification

Notice: If verification is not fulfilled please increase length a.



$M_{c,Rk,B}$	8,17	[kNm/m]	$M_{B,Ed}$	5,57	[kNm/m]
$R_{w,Rk,B}$	22,82	[kN/m]	$R_{B,Ed}$	10,22	[kN/m]
$R_{w,Rk,B,laB=160}$	22,89	[kN/m]	$V_{L,Ed}$	5,14	[kN/m]
$V_{w,Rk}$	28,49	[kN/m]	b_R	0,31	[m]
γ_M	1,10	[-]	length a	0,80	[m]
$\Sigma F_{v,Rd}$	3,50	[kN]	φ	66,00	[°]

Notice: $R_{w,Rk,B,laB=160\,mm}$ for oppostite profile position

$\Sigma F_{v,Rd} = n \times F_{v,Rd}$ shear resistance value according to EN 1993-1-3 or ETA at each coupling point

Bending moment distribution like for continuous profile.

a.) Verification of the profile at intermediate support

	$M_{B,Ed} / M_{c,Rd,B} \leq 1.0$	0,75	[-]
downward load:	$R_{B,Ed} / R_{w,Rd,B} \leq 1.0$	0,49	[-]
uplift load:	$V_{L,Ed} / V_{w,Rd} \leq 1.0$	0,20	[-]

Notice: Verification of M-R-interaction or M-V-interaction according to used type design must be done additionally depending on downward or uplift design loads.

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 and uplift load:

No additional verification necessary

c.) Verification of the connections

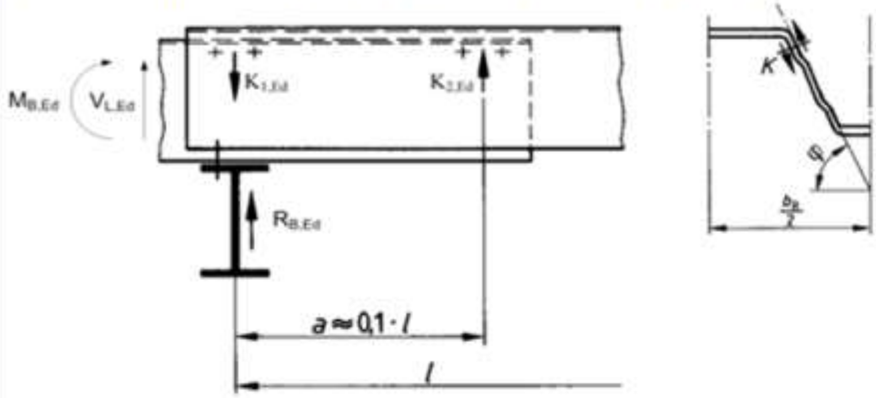
$K_{Ed} = M_{B,Ed} / a / (2 \times \sin(\varphi)) \times b_R$	1,18	[kN]
$K_{Ed} / \Sigma F_{v,Rd} \leq 1.0$	0,34	[-]

***Figure 8.6.2a** – Excel tab for assembly with single overlap joint with cantilever above.*

Please fill in the red cells

Verification

Notice: If verification is not fulfilled please increase length a.



$M_{c,Rk,B}$	8,17	[kNm/m]	$M_{B,Ed}$	5,57	[kNm/m]
$R_{w,Rk,B}$	22,82	[kN/m]	$R_{B,Ed}$	10,22	[kN/m]
$R_{w,Rk,B,laB=160}$	22,89	[kN/m]	$V_{L,Ed}$	5,14	[kN/m]
$V_{w,Rk}$	28,49	[kN/m]	b_R	0,31	[m]
γ_M	1,10	[-]	length a	0,80	[m]
$\Sigma F_{v,Rd}$	3,50	[kN]	φ	66,00	[°]

Notice: $R_{w,Rk,B,laB=160\,mm}$ for oppostite profile position

$\Sigma F_{v,Rd} = n \times F_{v,Rd}$ shear resistance value according to EN 1993-1-3 or ETA at each coupling point

Bending moment distribution like for continuous profile.

a.) Verification of the profile at intermediate support

	$M_{B,Ed} / M_{c,Rd,B} \leq 1.0$	0,75	[-]
downward load:	$R_{B,Ed} / R_{w,Rd,B} \leq 1.0$	0,49	[-]
uplift load:	$V_{L,Ed} / V_{w,Rd} \leq 1.0$	0,20	[-]

Notice: Verification of M-R-interaction or M-V-interaction according to used type design must be done additionally depending on downward or uplift design loads.

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 and uplift load:

No additional verification necessary

c.) Verification of the connections

$K_{Ed} = M_{B,Ed} / a / (2 \times \sin(\varphi)) \times b_R$	1,18	[kN]
$K_{Ed} / \Sigma F_{v,Rd} \leq 1.0$	0,34	[-]

Figure 8.6.2b – *Excel tab for assembly with single overlap joint with cantilever underneath.*

Comparison between analytical result and Excel software result for single overlap joint with cantilever above

For this comparison, analytical result (paragraph 8.4.2), is the reference.

Object	Analytic	Excel software	Error [%]
Verification of the profile at intermediate support			
Downward loading			
Moment on support	0,751	0,75	-0,13 %
Reaction on support	0,493	0,49	-0,6 %
Uplift loading			
Shear resistance	0,199	0,20	0,5 %
Check of web-crippling			
Downward loading	0,67	0,67	0 %
Uplift loading	-	-	
Verification of the connection			
Load in connection	2,05	2,05	0 %
Resistance of connection	0,585	0,59	0,85 %

Table 8.6.2a – Comparison between analytical and *Excel tab results for assembly with single overlap joint with cantilever above.*

Values given by this software applying the design example drive to results strongly similar. All errors are less than ± 1 %.

Comparison between analytical result and Excel software result for single overlap joint with cantilever underneath

For this comparison, analytical result (paragraph 8.4.3), is the reference.

Object	Analytic	Excel software	Error [%]
Verification of the profile at intermediate support			
Downward loading			
Moment on support	0,751	0,75	-0,13 %
Reaction on support	0,493	0,49	-0,6 %
Uplift loading			
Shear resistance	0,199	0,20	0,5 %
Check of web-crippling	-	-	-
Verification of the connection			
Load in connection	1,18	1,18	0 %
Resistance of connection	0,338	0,34	0,59 %

Table 8.6.2b – Comparison between analytical and *Excel tab results for assembly with single overlap joint with cantilever underneath.*

Values given by this software applying the design example drive to results strongly similar. All errors are less than ± 1 %.

8.6.3. Validation of second case with building 2

For the building 2, the third and fourth tab of the Excel software are used.

First input data are the characteristics values of the profile, the considered safety factor γ_M and the total shear resistance value of fasteners (in web). They are implemented according Figure 8.6.3a and 8.6.3b:

- For downward loading:
  - Characteristic bending resistance on support for normal profile position under downward loading: $M_{c,Rk,B}^{(+)} = M_{b,Rd} = 8{,}17$ [kNm/m];
  - Characteristic resistance to intermediate support reaction (160 mm width of support): $R_{w,Rk,B}^{(+)} = R_{w,Rd,B} = 22{,}82$ [kN/m];
  - Characteristic bending resistance on support for opposite profile position under uplift loading: $M_{c,Rk,B}^{(-)} = M_{b,Rd} = 8{,}30$ [kNm/m];
  - Shear characteristic resistance: $V_{w,Rk}^{(-)} = V_{w,Rd} = 28{,}49$ [kN/m];
  - Safety factor γ_m of 1,10;
  - Total shear resistance of fasteners: $\sum F_{V,Rd} = 3{,}50$ kN;
  - Characteristic resistance to intermediate support reaction for opposite profile position (160 mm width of support): $R_{w,Rk,B,160mm} = R_{w,Rd,B,la=160} = 22{,}89$ [kN/m].
- For uplift loading:
  - Bending characteristic resistance on support for normal profile position under uplift loading: $M_{c,Rk,B}^{(+)} = M_{b,Rd} = 9{,}66$ [kNm/m];
  - Shear characteristic resistance: $V_{w,Rk}^{(+)} = V_{w,Rd} = 28{,}49$ [kN/m];
  - Bending characteristic resistance on support and at the end of the overlap for opposite profile position under downward loading: $M_{c,Rk,B}^{(-)} = M_{b,Rd} = 9{,}66$ [kNm/m];
  - Characteristic resistance to intermediate support reaction for opposite profile position (160 mm width of support): $R_{w,Rd,B,la=160} = 22{,}89$ [kN/m];
  - Safety factor γ_m of 1,10;
  - Total shear resistance of fasteners: $\sum F_{V,Rd} = 3{,}50$ kN;

Second input data are the application of load combination, see paragraph 8.1.4 as follow:

- For downward loading:
  - Moment on intermediate support $M_{B,Ed} = 9{,}33$ kNm/m;

- Reaction on intermediate support of: $R_{B,Ed} = 17{,}12$ kN/m;
- Moment at the end of overlap length a (left side of the support): $M_{I,Ed} = 3{,}29$ kNm/m;
- Moment at the end of overlap length a (right side of the support): $M_{II,Ed} = 3{,}29$ kNm/m;
- Pitch of the profile: b_R = 0,31 m;
- Overlap length: a = 0,80 m;
- Web angle: φ = 66°.

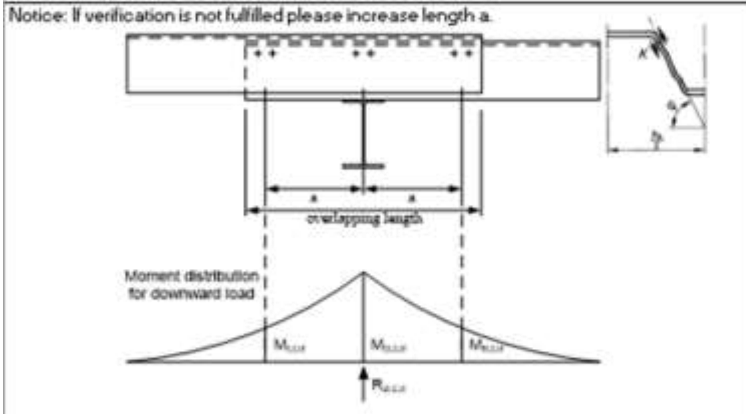
- For uplift loading:
  - Moment on intermediate support $M_{B,Ed} = 2{,}82$ kNm/m;
  - Shear load of $V_{Ed} = V_{L,Ed} = 2{,}59$ kN/m;
  - Moment at the end of overlap length a (left side of the support): $M_{I,Ed} = 0{,}99$ kNm/m;
  - Moment at the end of overlap length a (right side of the support): $M_{II,Ed} = 0{,}99$ kNm/m;
  - Pitch of the profile: b_R = 0,31 m;
  - Overlap length: a = 0,80 m;
  - Web angle: φ = 66°.

Please fill in the red cells

Verification

downward load

Notice: If verification is not fulfilled please increase length a.



$M_{c,Rk,B}^{(+)}$	8.17	[kNm/m]	a.)	$M_{B,Ed}$	9.33	[kNm/m]
$R_{w,Rk,B}^{(+)}$	22.82	[kN/m]		$R_{B,Ed}$	17.12	[kN/m]
$M_{c,Rk,B}^{(-)}$	8.30	[kNm/m]		$M_{I,Ed}$	3.29	[kNm/m]
$V_{w,Rk}^{(-)}$	28.49	[kN/m]		$M_{II,Ed}$	3.29	[kNm/m]
γ_M	1.10	[-]		b_R	0.31	[m]
$\Sigma F_{v,Rd}$	3.50	[kN]		length a	0.80	[m]
$R_{w,Rk,B,160mm}$	22.89	[kNm/m]		φ	68.00	[°]

Notice: (+) normal profile position downward load
(-) opposite profile position uplift load
$R_{w,Rk,B,160mm}$ for opposite profile position downward load
$\Sigma F_{v,Rd} = n \times F_{v,Rd}$ shear resistance value according to EN 1993-1-3 or ETA at each coupling point
Bending moment distribution like for continuous profile without taking into account the higher stiffness at the support area.

b.) Verification of the profile at intermediate support

$M_{B,Ed}/(1.8 \times M_{c,Rd,B}^{(+)}) \leq 1.0$	0,70	[-]
$R_{B,Ed}/(1.8 \times R_{w,Rd,B}^{(+)}) \leq 1.0$	0,46	[-]

Notice: Verification of interaction according to used type design must be done additionally.

c.) Verification of the continuous profile at the end of the overlap with the bending moments $M_{I,Ed}$ or $M_{II,Ed}$ and the line load F_{Ed}

$F_{Ed} = M_{B,Ed}/(2 \times a)$	5,83	[kN/m]

Section I and II:

$M_{I,Ed}/M_{c,Rd,B}^{(-)} \leq 1.0$	0,44	[-]
$M_{II,Ed}/M_{c,Rd,B}^{(-)} \leq 1.0$	0,44	[-]
$F_{Ed}/V_{w,Rd}^{(-)} \leq 1.0$	0,23	[-]

Notice: Verification of interaction according to used type design must be done additionally for section I and II.

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

cantilever:	upside		underneath
$M_{B,Ed}/(2 \times a)/(0.5 \times R_{w,B,Rd,160mm}) \leq 1.0$	0,56	[-]	not necessary

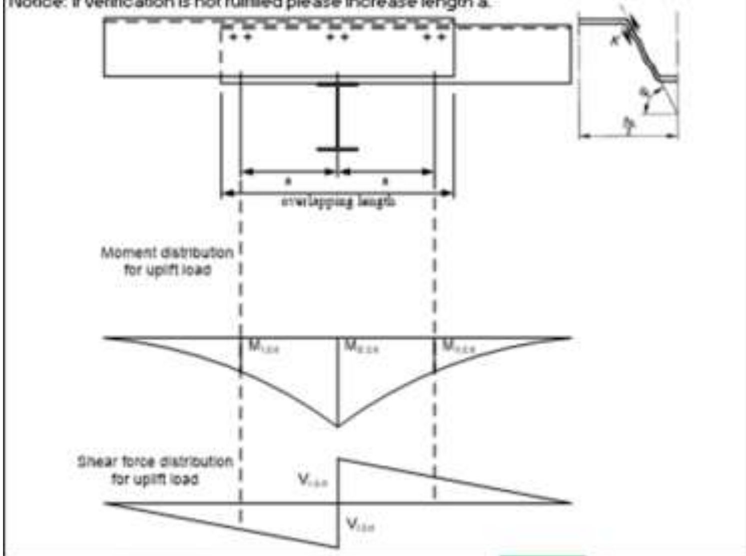
e.) Verification of the connections

$K_{Ed} = M_{B,Ed}/(2 \times a)/(2 \times \sin(\varphi)) \times b_R$	0,99	[kN]
$K_{Ed}/\Sigma F_{v,Rd} \leq 1.0$	0,28	[-]

***Figure 8.6.3a** – Excel tab for assembly with double overlap joint – downward loading.*

uplift load

Notice: If verification is not fulfilled please increase length a.



$M_{c,Rk,B}^{(+)}$	3,66	[kNm/m]	a.)	$M_{B,Ed}$	2,82	[kNm/m]
$V_{w,Rk}^{(+)}$	28,43	[kN/m]		max V_{Ed}	2,59	[kN/m]
$M_{c,Rk,B}^{(-)}$	3,66	[kNm/m]		$M_{I,Ed}$	0,99	[kNm/m]
$R_{w,Rk,B}^{(-)}$	22,89	[kN/m]		$M_{II,Ed}$	0,99	[kNm/m]
γ_{M}	1,10	[-]		b_R	0,31	[m]
$\Sigma F_{v,Rd}$	3,50	[kN]		length a	0,80	[m]
				φ	66,00	[°]

Notice: (+) normal profile position uplift load
(-) opposite profile position downward load, values for max $L_{w,B}$
$R_{w,Rk,B,160mm}$ for opposite profile position downward load
$\Sigma Fv,Rd = n \times F_{v,Rd}$ shear resistance value according to EN 1993-1-3 or ETA at each coupling point
Bending moment distribution like for continuous profile without taking into account the higher stiffness at the support area.

b.) Verification of the profile at intermediate support

$M_{B,Ed} / (1.8 \times M_{c,Rd,B}^{(+)}) \leq 1.0$	0,18	[-]
max $V_{Ed} / (1.8 \times V_{w,Rd}^{(+)}) \leq 1.0$	0,06	[-]

Notice: Verification of interaction according to used type design must be done additionally.

c.) Verification of the continuous profile at the end of the overlap with the bending moments $M_{I,Ed}$ or $M_{II,Ed}$ and the line load F_{Ed}

	$F_{Ed} = M_{B,Ed} / (2 \times a)$	1,76	[kN/m]
Section I and II:	$M_{I,Ed} / M_{c,Rd,B}^{(-)} \leq 1.0$	0,11	[-]
	$M_{II,Ed} / M_{c,Rd,B}^{(-)} \leq 1.0$	0,11	[-]
	$F_{Ed} / R_{w,Rd,B}^{(-)} \leq 1.0$	0,08	[-]

Notice: Verification of interaction according to used type design must be done additionally for section I and II.

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

cantilever:	upside	underneath
	not necessary	not necessary

e.) Verification of the connections

$K_{Ed} = M_{B,Ed} / (2 \times a) / (2 \times \sin(\varphi)) \times b_R$	0,30	[kN]
$K_{Ed} / \Sigma F_{v,Rd} \leq 1.0$	0,09	[-]

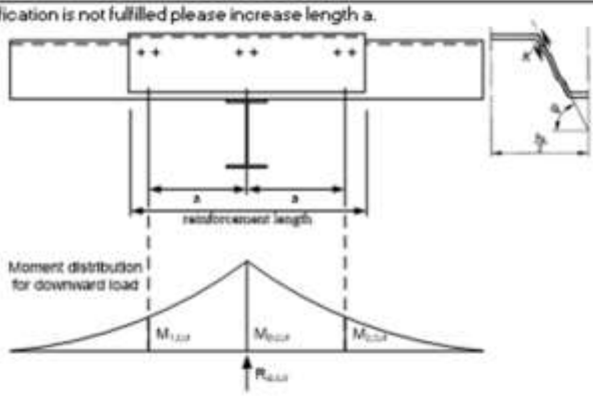
***Figure 8.6.3b** – Excel tab for assembly with double overlap joint – uplift loading.*

Please fill in the red cells

Verification

downward load

Notice: If verification is not fulfilled please increase length a.



$M_{c,Rk,B}^{(+)}$	8.17	[kNm/m]	a.)	$M_{B,Ed}$	9.33	[kNm/m]
$R_{w,Rk,B}^{(+)}$	22.82	[kN/m]		$R_{B,Ed}$	17.12	[kN/m]
$M_{c,Rk,B}^{(-)}$	8.30	[kNm/m]		$M_{I,Ed}$	3.29	[kNm/m]
$V_{w,Rk}^{(-)}$	28.49	[kN/m]		$M_{II,Ed}$	3.29	[kNm/m]
γ_M	1.10	[-]		b_R	0.31	[m]
$\Sigma F_{v,Rd}$	3.60	[kN]		length a	0.80	[m]
$R_{w,Rk,B,160mm}$	22.89	[kNm/m]		φ	66.00	[°]

Notice: (+) normal profile position downward load
(-) opposite profile position uplift load
$R_{w,Rk,B,160mm}$ for opposite profile position downward load
$\Sigma F_{v,Rd} = n \times F_{v,Rd}$ shear resistance value according to EN 1993-1-3 or ETA at each coupling point
Bending moment distribution like for continuous profile without taking into account the higher stiffness at the support area.

b.) Verification of the profile at intermediate support

$M_{B,Ed} / (1.8 \times M_{c,Rd,B}^{(+)}) \leq 1.0$ 0,70 [-]
$R_{B,Ed} / (1.8 \times R_{w,Rd,B}^{(+)}) \leq 1.0$ 0,46 [-]

Notice: Verification of interaction according to used type design must be done additionally.

c.) Verification of the continuous profile at the end of the overlap with the bending moments $M_{I,Ed}$ or $M_{II,Ed}$ and the line load F_{Ed}

$F_{Ed} = M_{B,Ed} / (2 \times a)$ 5,83 [kN/m]

$\max M_{i,Ed} / M_{c,Rd,B}^{(-)} \leq 1.0$ 0,44 [-]
$F_{Ed} / V_{w,Rd}^{(-)} \leq 1.0$ 0,23 [-]

Notice: Verification of interaction according to used type design must be done additionally.

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

$M_{B,Ed} / (2 \times a) / (0.5 \times R_{w,B,Rd,(sB-160)}) \leq 1.0$ 0,56 [-]

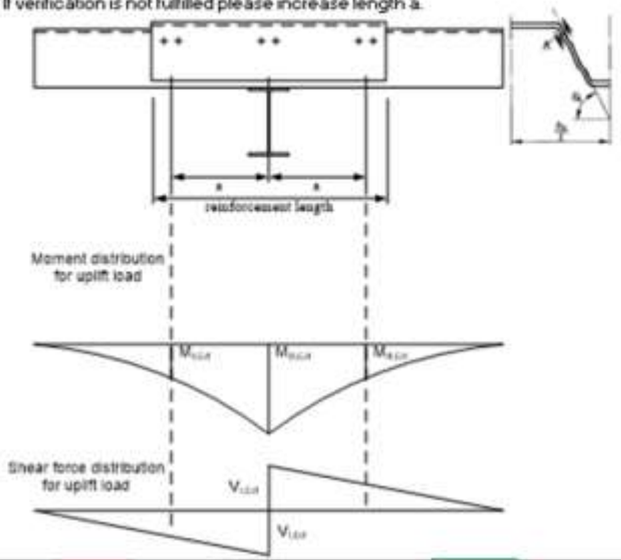
e.) Verification of the connections

$K_{Ed} = M_{B,Ed} / (2 \times a) / (2 \times \sin(\varphi)) \times b_R$ 0,99 [kN]
$K_{Ed} / \Sigma F_{v,Rd} \leq 1.0$ 0,28 [-]

Figure 8.6.3c *– Excel tab for assembly of continuous profile with local reinforcement – downward loading.*

uplift load

Notice: If verification is not fulfilled please increase length a.



$M_{c,Rk,B}^{(+)}$	3,66	[kNm/m]	a.)	$M_{B,Ed}$	2,82	[kNm/m]
$V_{w,Rk}^{(+)}$	28,49	[kN/m]		max V_{Ed}	2,59	[kN/m]
$M_{c,Rk,B}^{(-)}$	3,66	[kNm/m]		$M_{I,Ed}$	0,39	[kNm/m]
$R_{w,Rk,B}^{(-)}$	22,89	[kN/m]		$M_{II,Ed}$	0,39	[kNm/m]
γ_M	1,10	[-]		b_R	0,31	[m]
$\Sigma F_{v,Rd}$	3,50	[kN]		length a	0,80	[m]
				φ	68,00	[°]

Notice: (+) normal profile position uplift load
(-) opposite profile position downward load, values for max $L_{a,B}$
$R_{w,Rk,B,160mm}$ for opposite profile position downward load
$\Sigma F_{v,Rd} = n \times F_{v,Rd}$ shear resistance value according to EN 1993-1-3 or ETA at each coupling point
Bending moment distribution like for continuous profile without taking into account the higher stiffness at the support area.

b.) Verification of the profile at intermediate support

$M_{B,Ed} / (1.8 \times M_{c,Rd,B}^{(+)}) \leq 1.0$	0,18	[-]
max $V_{Ed} / (1.8 \times V_{w,Rd}^{(+)}) \leq 1.0$	0,06	[-]

Notice: Verification of interaction according to used type design must be done additionally.

c.) Verification of the continuous profile at the end of the overlap with the bending moments $M_{I,Ed}$ or $M_{II,Ed}$ and the line load F_{Ed}

$F_{Ed} = M_{B,Ed} / (2 \times a)$	1,76	[kN/m]
max$M_{I,Ed} / M_{c,Rd,B}^{(-)} \leq 1.0$	0,11	[-]
$F_{Ed} / R_{w,Rd,B}^{(-)} \leq 1.0$	0,08	[-]

Notice: Verification of interaction according to used type design must be done additionally.

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

not necessary

e.) Verification of the connections

$K_{Ed} = M_{B,Ed} / (2 \times a) / (2 \times \sin(\varphi)) \times b_R$	0,30	[kN]
$K_{Ed} / \Sigma F_{v,Rd} \leq 1.0$	0,09	[-]

***Figure 8.6.3d** – Excel tab for assembly of continuous profile with local reinforcement – uplift loading.*

Comparison between analytical result and Excel software result for assembly with double overlap joint

For this comparison, analytical result (paragraph 8.5.3), is the reference.

Object	Analytic	Excel software	Error [%]
Verification of the profile at intermediate support			
Downward loading			
Moment on support	0,699	0,70	0,14 %
Reaction on support	0,459	0,46	0,22 %
Uplift loading			
Moment on support	0,178	0,18	1,12 %
Shear resistance	0,056	0,06	7,14 %
Verification at the end of the overlap			
Downward loading			
Applied load	5,83	5,83	0 %
Moment at the end of overlap	0,436	0,44	0,92 %
Shear resistance	0,225	0,23	2,22 %
Uplift loading			
Applied load	1,76	1,76	0 %
Moment at the end of overlap	0,113	0,11	-2,65 %
Reaction resistance	0,085	0,08	-5,88 %
Check of web-crippling			
Downward loading	0,561	0,56	-0,17 %
Uplift loading	-	-	--
Verification of the connection			
Downward loading			
Load in connection	0,99	0,99	0 %
Resistance of connection	0,283	0,28	-1,06 %
Uplift loading			
Load in connection	0,30	0,30	0 %
Resistance of connection	0,085	0,09	5,88 %

Table 8.6.3a – Comparison between analytical and *Excel tab results for assembly with double overlap joint.*

Analytical results were presented with 3 digits after decimal while Excel software presents results with 2 digits. Consequently, more the result value is weak, more the error between Excel software and analytical results is great.

If analytical results are presented with 2 digits, like excel software, error is less than ± 1 %. So finally, values given by this software applying the design example are acceptable.

Comparison between analytical result and Excel software result for assembly of continuous profile with local reinforcement

For this comparison, analytical result (paragraph 8.5.4), is the reference.

Object	Analytic	Excel software	Error [%]
Verification of the profile at intermediate support			
Downward loading			
Moment on support	0,699	0,70	0,14 %
Reaction on support	0,459	0,46	0,22 %
Uplift loading			
Moment on support	0,178	0,18	1,12 %
Shear resistance	0,056	0,06	7,14 %
Verification at the end of the overlap			
Downward loading			
Applied load	5,83	5,83	0 %
Moment at the end of overlap	0,436	0,44	0,92 %
Shear resistance	0,225	0,23	2,22 %
Uplift loading			
Applied load	1,76	1,76	0 %
Moment at the end of overlap	0,113	0,11	-2,65 %
Reaction resistance	0,085	0,08	-5,88 %
Check of web-crippling			
Downward loading	0,561	0,56	-0,17 %
Uplift loading	-	-	-
Verification of the connection			
Downward loading			
Load in connection	0,99	0,99	0 %
Resistance of connection	0,283	0,28	-1,06 %
Uplift loading			
Load in connection	0,30	0,30	0 %
Resistance of connection	0,085	0,09	5,88 %

Table 8.6.3a **–** Comparison between analytical and *Excel tab results for assembly of a continuous profile with local reinforcement.*

Conclusion for this comparison is the same than previously for double overlap joint.

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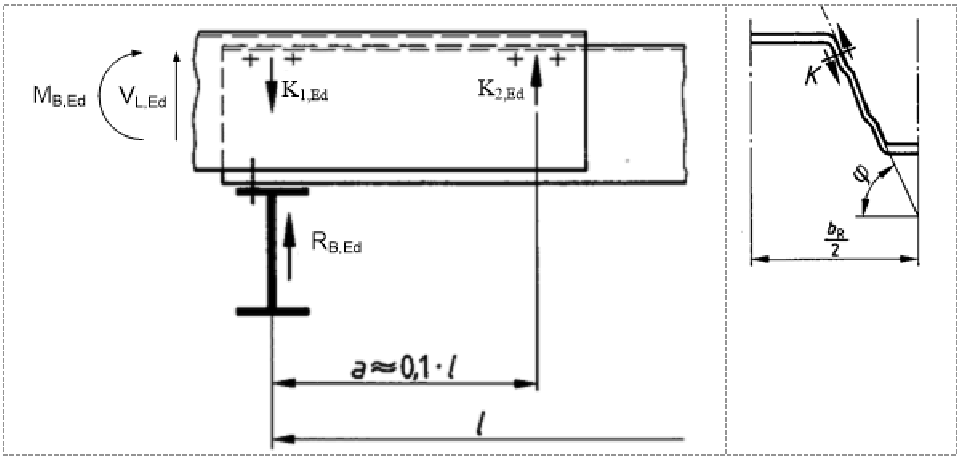
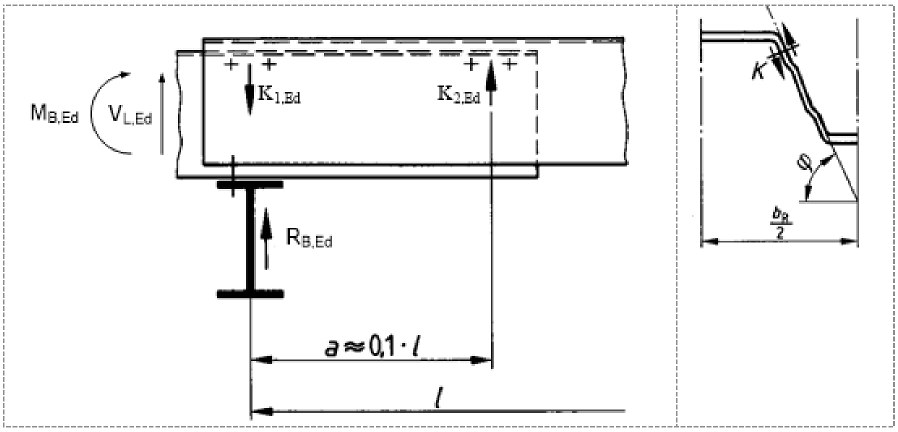
ANNEX: AMENDMENT PROJECT SUBMITTED TO CEN

AM-1-3-2016-08	
Subject	Assembled trapezoidal profiles (statically effective overlapping)
Clause No/ Subclause No/ Annex	
Reason for Amendment	No data in the actual version of EN 1993-1-3
Proposed Change	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 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} $K_{Ed} = \max K_i = \lvert M_{B,Ed} / a + V_{L,Ed}\rvert / (2*\sin(\varphi))*b_R$ (Verification in one web) $K_{Ed} / \Sigma F_{v,Rd} \leq 1{,}0$ 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 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

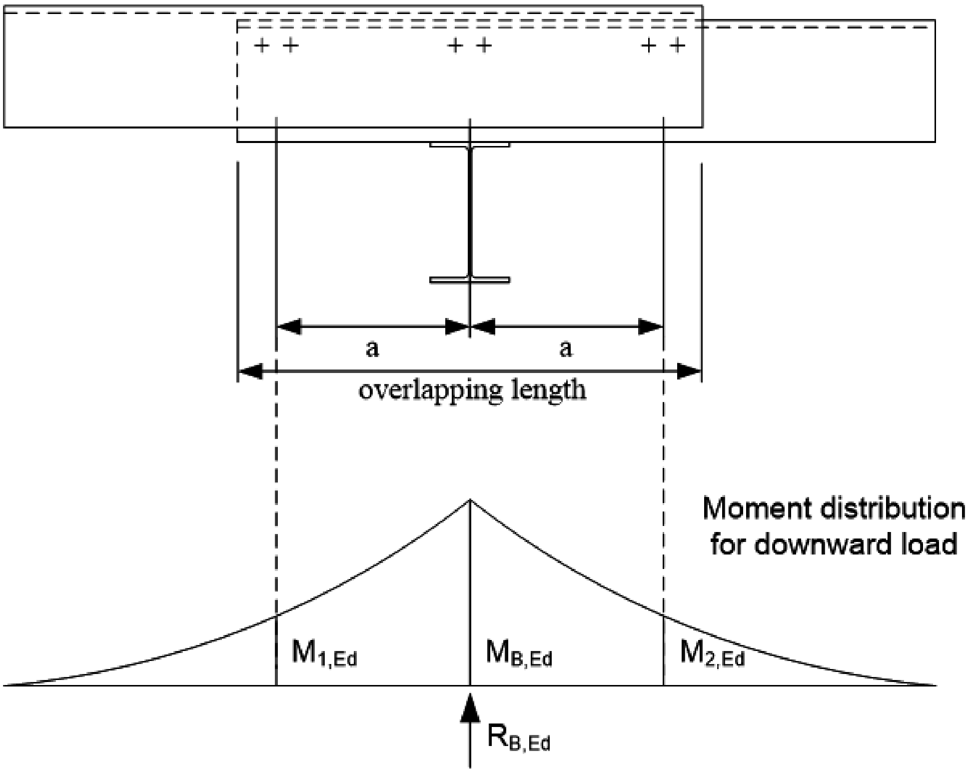
c) Verification of the connections K_{Ed}

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

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

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 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.

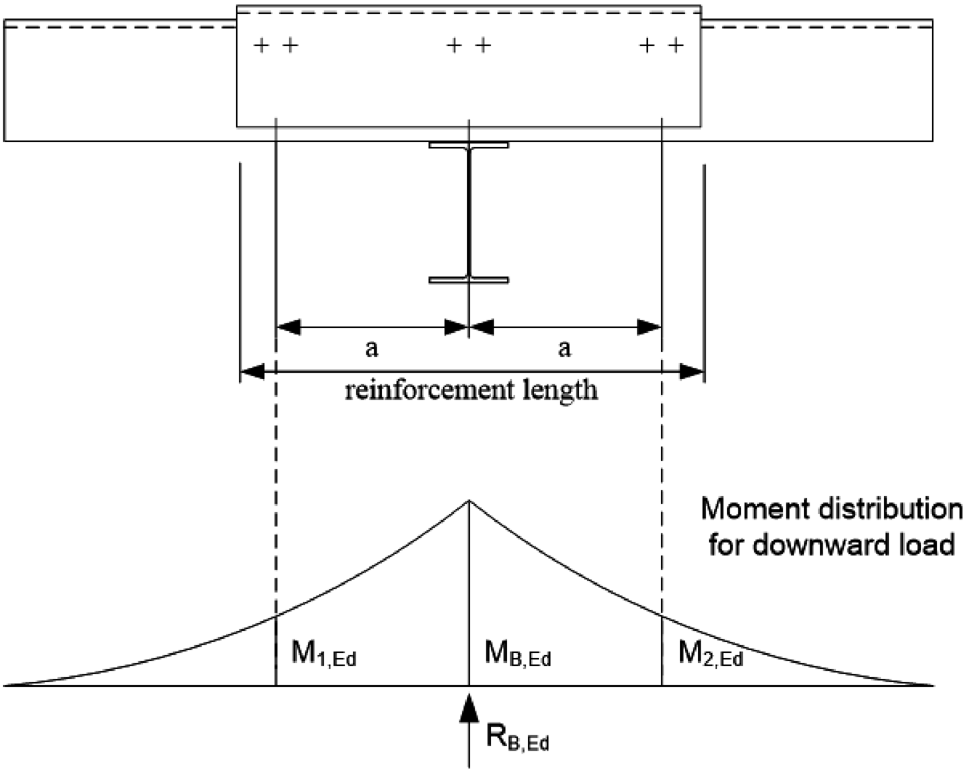
e) Verification of the connections K_{Ed}
with

K_{Ed} = max K_i = $|M_{B,Ed}|/(4*a*\sin(\varphi))*b_R$ (Verification in one web)

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

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 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 $R_{w,Rd,B}(160\ \text{mm})$ is suitable for this verification)

- Uplift load = positive bending moment
No web crippling possible at the end of both cantilevers

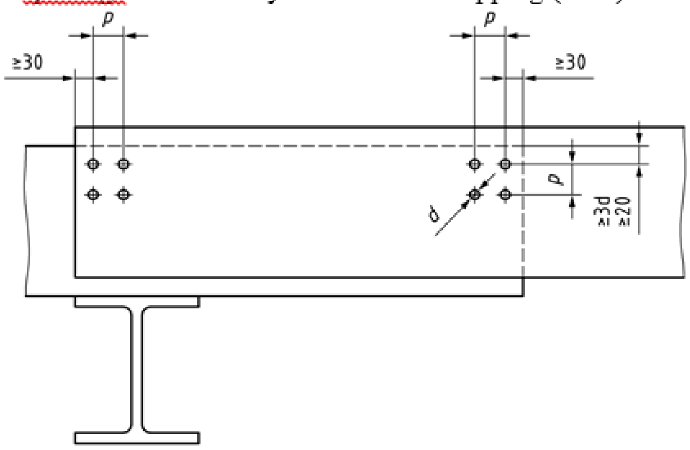
e) Verification of the connections K_{Ed}
with

$K_{Ed} = \max K_i = |M_{B,Ed}|/(4 * a * \sin(\varphi)) * b_R$ (Verification in one web)

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

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

Edge and hole spacings for statically effective overlapping (1.-4.)



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