GRISPE

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

Working Package 2

Liner trays

Test analysis and interpretation

31st October 2015

Deliverable D 2.4

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

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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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1. Introduction

Façades with liner trays are mostly cladded with trapezoidal sheeting on the outer side. In general, the outer cladding works as a diaphragm and stabilizes the small flanges of the liner trays against lateral displacements. The stabilizing effect depends on the distance s_1 between the fixings of the outer cladding.

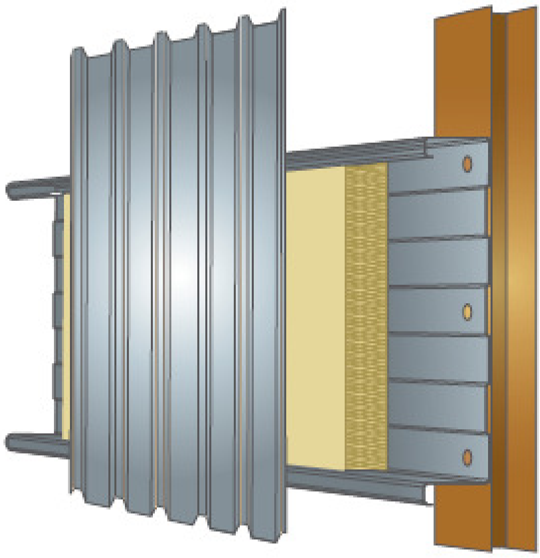

Fig. 1: Typically two layer build-up wall cladding system with liner trays

The positive bending moment is the load bearing value, which is influenced by the fixing distance s_1. Under positive bending moment, the small flanges of the liner trays are compressed; the bearing capacity is reached, when the small flanges fail by lateral buckling. The fixing distance s_1 controls the buckling length of the small flanges and therefore the ultimate bending moment of the liner trays.

Two types of tests were executed; both tests lead to positive bending moments in the liner trays. Single span tests with positive loading simulating the situation in the span of the liner trays under wind pressure and 3-point-bending-tests, which represent the area at intermediate supports under wind suction load, were executed. By varying the distance s_1 the influence on the load bearing capacity of the liner trays was studied.
In this report, the tests are evaluated and the ultimate bending moments of the liner trays depending of the fixing distance s_1 are determined.

2. Description of the considered profiles
2.1 Cross sections

Two different liner trays were tested:

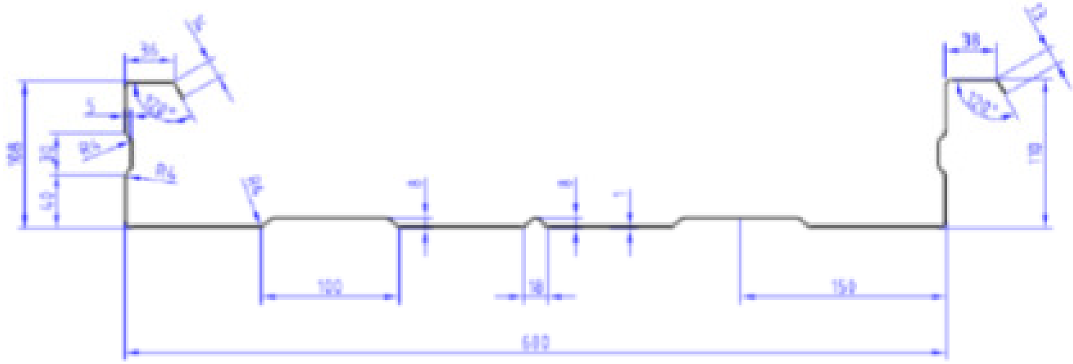

Fig. 2: Cross section of the liner tray JID 110/600

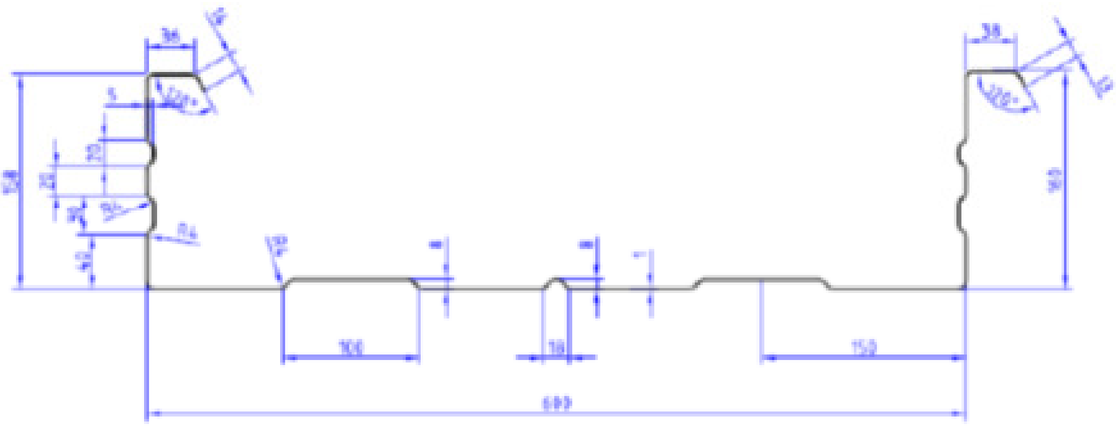

Fig. 3: Cross section of the liner tray JID 110/600

As outer cladding trapezoidal sheets JID 35/207, sheet thickness 0,63 mm, were used.

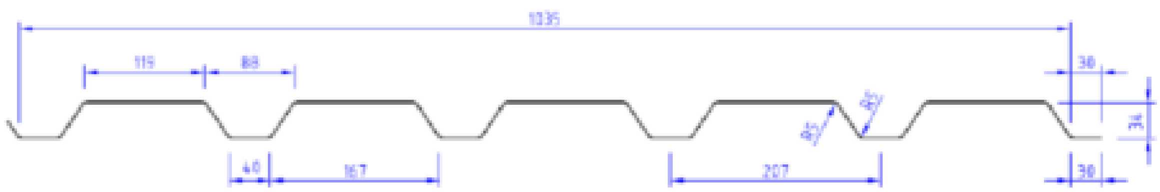

Fig. 4: Cross section of the trapezoidal sheeting JID 35/207

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 liner trays are produced from coils steel grade S320 GD according to EN 10346. The nominal values are:

- Yield strength f_{yb} = 320 N/mm²
- Tensile strength f_u = 390 N/mm²
- Elongation at fracture A_{80} = 17 % (*)
- Youngs modulus E = 21000 N/mm²

The specimens were produced and provided in several deliveries.

The specimens were provided in several deliveries. Form each delivery, 3 samples per profile type and nominal thickness were worked out, and the material properties were determined by tensile tests according to EN 6892-1:2009.

The results show, that the specimens JID 110/600, thickness 0,75 mm and thickness 1,00 mm, of all deliveries have the same properties (see annex). Therefore, the overall mean values are considered as representative for these specimens. These mean values are taken as observed values as well as reference values. Since observed values and reference values are considered as sufficiently identical, no adjustment of the test results to take into account variations of properties is necessary.

The specimens JID 160/600 are obviously produced from different coils; the properties of the different batches are significantly different. The mean values of a three-sample-series are considered as representative for the specimens of this batch (delivery). In order to equalize the influence of the material properties, the test results of different batches are adjusted to identical reference values.

Table 1 defines the representative observed material properties and the corresponding reference values for each type and nominal thickness. Since the test results depend only on the sheet thickness and the yield strength, the tensile strength and the elongation at fracture are not mentioned.

Liner tray type	Nominal thickness t_N (mm) 0,75	Delivery/ batch	Observed values		Reference values	
			Core thickness t_{cor} (mm)	Yield strength f_{yb} (N/mm²)	Core thickness t_{cor} (mm)	Yield strength f_{yb} (N/mm²)
JID 110/600	0,75	1	0,691	352,6	0,691	352,6
		2	0,691	352,6		
		3	0,691	352,6		
JID 110/600	1,00	1	0,962	336,2	0,962	336,2
		2	0,962	336,2		
JID 160/600	0,75	1	0,700	334,0	0,700	347,7
		2	0,665	355,0		
		3	0,700	347,7		
JID 160/600	1,00	1	0,963	353,7	0,963	353,7
		2	0,950	334,7		

Table 1: Observed material properties and reference values

3. Principles of test evaluation

3.1 Adjustment of test results

The test results are adjusted to allow for variations between the actual measured properties of the test specimens and their chosen reference values. By this adjustment, the influence of the varying material properties is more or less equalized, and the interesting behaviour is not overlaid by variations of the thickness and yield strength.

$$R_{adj} = \frac{R_{obs}}{\mu_R}$$

R_{obs} obeserved test result

R_{adj} adjusted test result

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

$\alpha = 0,5$

$\beta = 1$ if $t_{cor} \geq t_{cor,obs}$

$\beta = 2$ if $t_{cor} < t_{cor,obs}$

t_{cor} reference value of the steel core thickness (see table 1)

$t_{cor,obs}$ for the considered batch representative mean value of the steel core thickness, determined by tensile tests (see table 1)

f_{yb} reference value of the yield strength (see table 1)

$f_{yb,obs}$ for the considered batch representative mean value of the yield strength, determined by tensile tests (see table 1)

3.2 Characteristic values

The characteristic values of the searched bearing properties are determined by an 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. So, all single span tests perform one test series as well as all internal support tests.

Each test series consist of several subsets; a subset is a small series of tests with identical conditions (same profile type, same nominal sheet thickness, same test setup, same fixing distance s_1 etc.). Normally, a subset consists of 2 or 3 identical tests.

The test results of a subset are referred to its specific mean value R_m; 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 evaluation

4.1 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)
Liner tray JID 110/600	0,75	0,089
	1,00	0,118
Liner tray JID 160/600	0,75	0,098
	1,00	0,133
Cladding JID 35/207	0,63	0,060

Table 3: self weight of the tested profiles

4.2 Single span tests

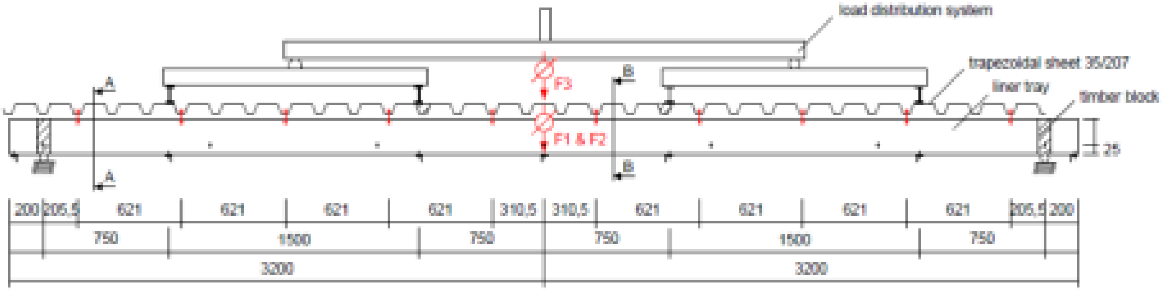

Fig. 5: Test setup single span tests

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. 5 shows a test specimen with the fixing distance s_1 = 621 mm (= 3 rips of the cladding profile JID 35/207). The fixing distances 1242 mm and 1863 mm are realized by fixing the cladding profile in every 6^{th} respectively 9^{th} rib.

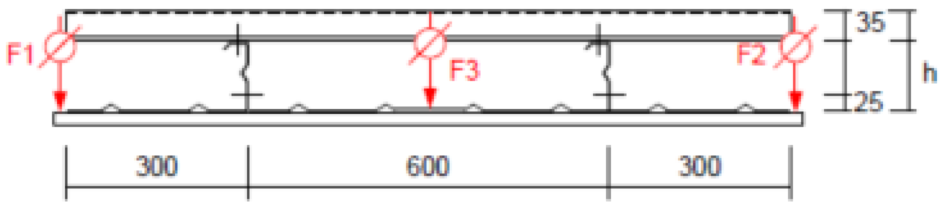

Fig. 6: Cross section of a test specimen

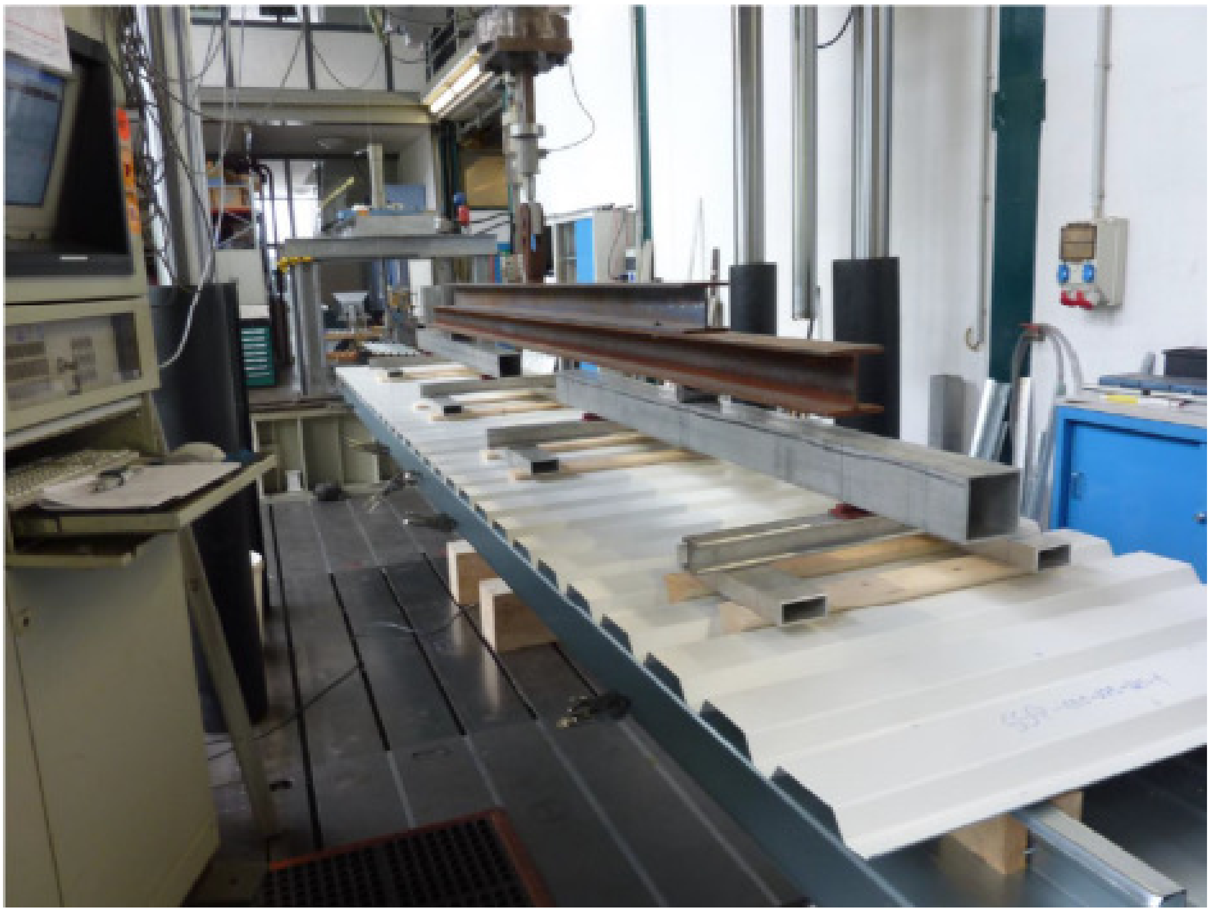

Fig. 7: Real setup of the single span tests

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 = 1,20 m)
L_V	length of the test specimen (here: L_V = 6,40 m)
L	span length (here: L = 6,00 m)

g self weight of the test specimen according to table 3

The self weight of the specimen is composed of the liner tray and the cladding profile

The detailed test evaluation is presented in the annex. The main results are:

s_1 mm	ultimate span moment $M_{c,Rk,F}$ (kNm/m)			
	JID 110-0,75	JID 110-1,00	JID 160-0,75	JID 160-1,00
621	3,50	6,54	5,35	9,92
1242	3,19	6,05	3,87	7,93
1863	2,98	5,71	3,56	6,61
6000[1)]	2,69	5,59	2,94	6,34

1) Tests without outer cladding

Table 4: Test results (characteristic bending moment) of the single span tests

In order to determine the lower limit of the bending moment capacity of the liner trays, tests with pure liner trays without any outer cladding were performed. In that case, no stabilizing effect of the outer cladding exists. The compressed small flanges of the liner trays are only stabilized against lateral buckling by the lateral bending stiffness of the webs of the liner trays and not by any restraining outer cladding. The buckling length of the small flanges is round about the span length,

Fig. 8: Single span test without outer cladding

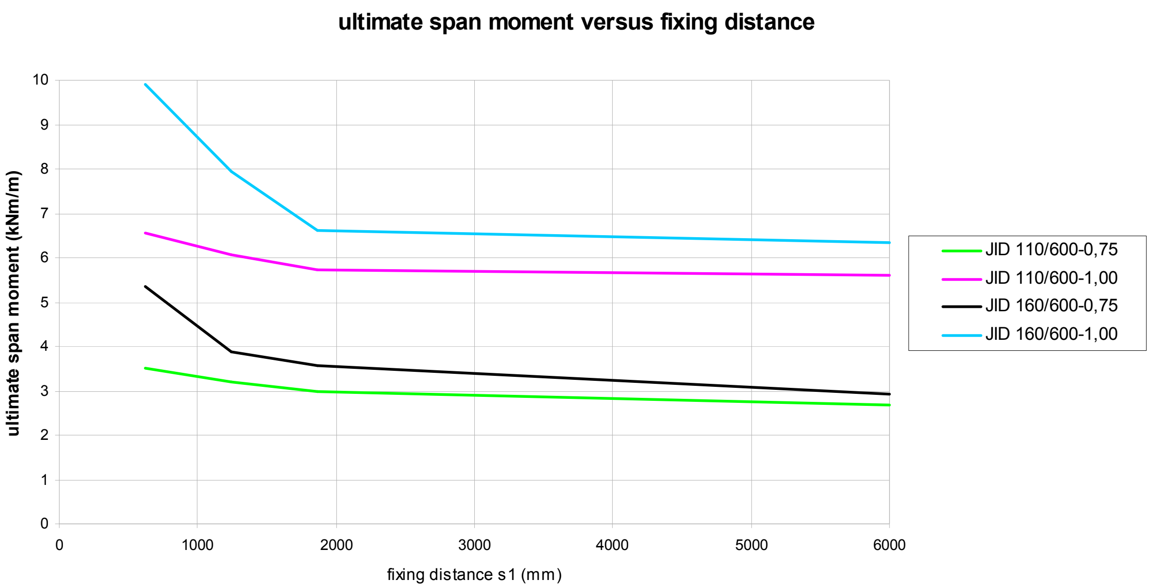

Fig. 9: Graphic view of the test results: characteristic bending moment depending of the fixing distance s_1

For a better comparison between the different types of liner trays and sheet thicknesses the graphic presentation is modified in that way, that all values are related to the characteristic bending moment for a fixing distance s_l = 621 mm.

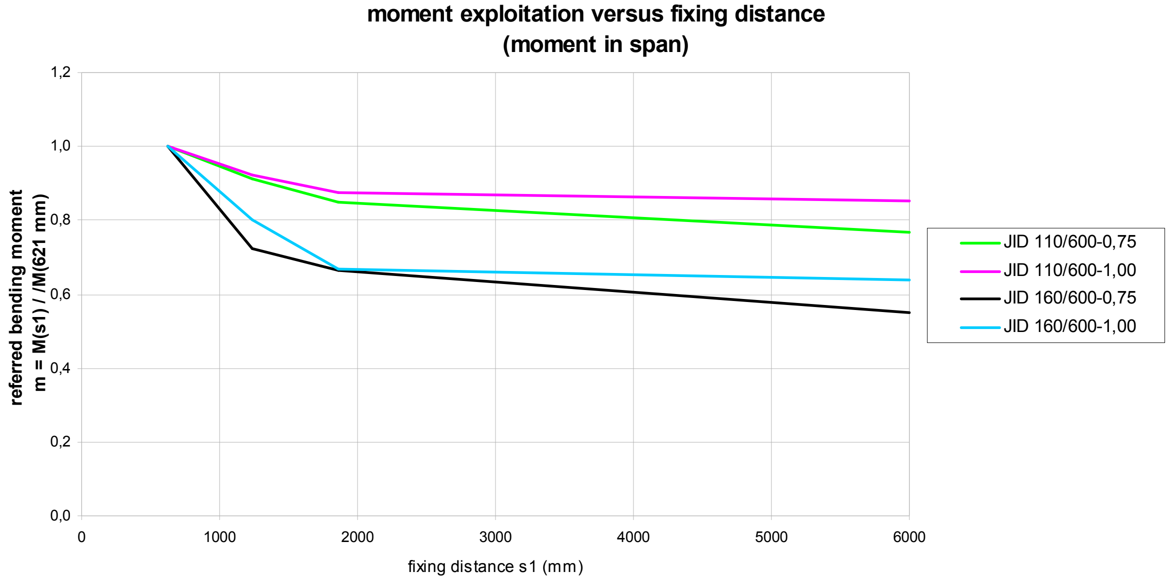

Fig. 10: Graphic view of the test results: related characteristic bending moment depending of the fixing distance s_l

The effect of the fixing distance s_l on the bending moment is very similar for different sheet thicknesses; but the height of the liner tray plays a more important roll. For higher liner trays the drop of the bending moment with increasing fixing distance is greater.

4.3 Internal support tests

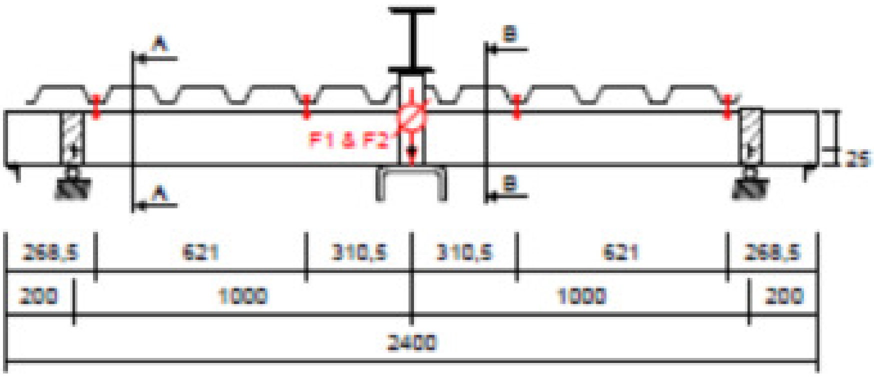

Fig. 11: Test setup internal support tests

The load is applied as line load in midspan. The load is introduced with a transverse beam into the bottom of the liner trays.

Fig. 10 shows a test specimen with the fixing distance s_l = 621 mm (= 3 rips of the cladding profile JID 35/207). The fixing distances 1242 mm and 1863 mm are realized by fixing the cladding profile in every 6^{th} respectively 9^{th} rib.

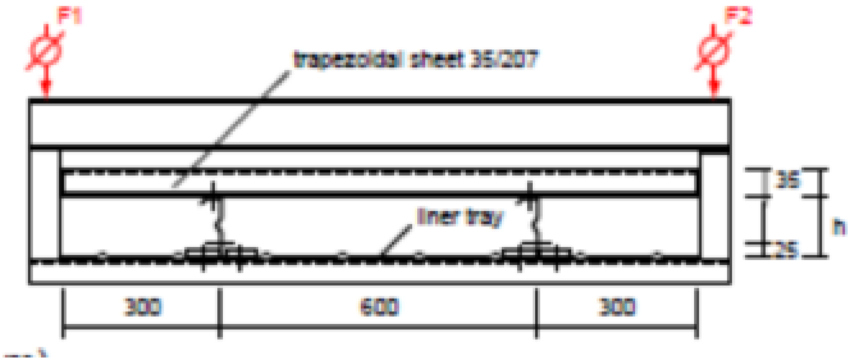

Fig. 12: Cross section of a test specimen in midspan, showing the transverse beam to apply the load into the bottom of the liner trays.

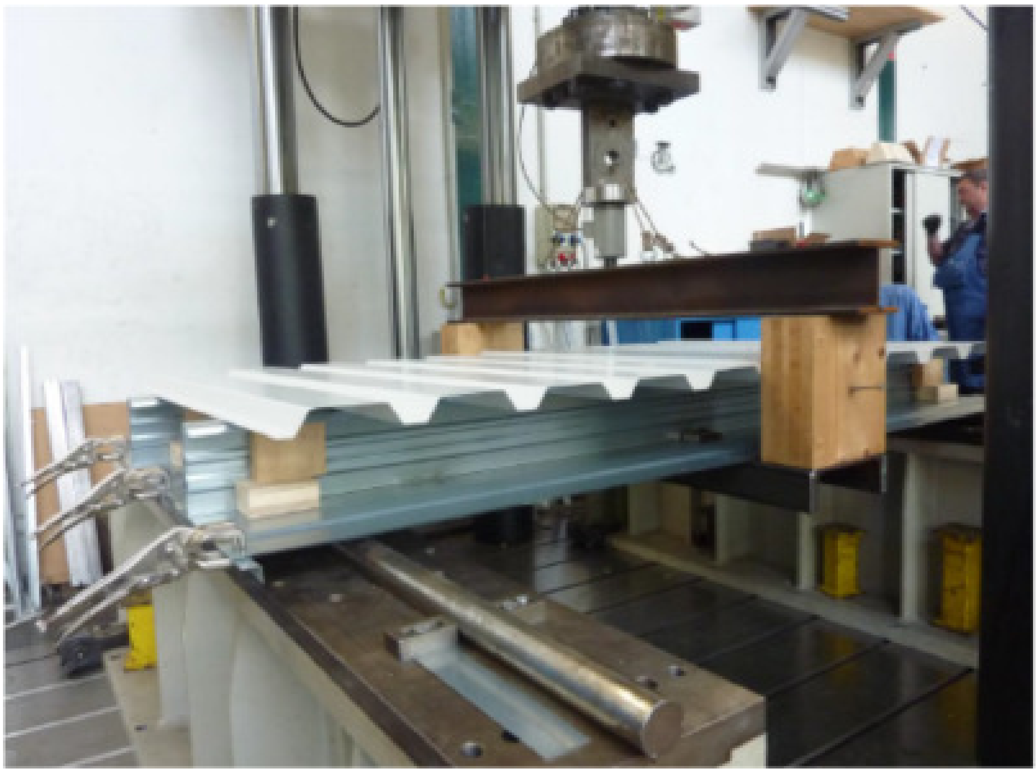

Fig. 13: Real setup of the internal support tests

Maximum bending moment in span:
This bending moment represents the bending moment at internal support under uplift load.

$M_{c,Rk,B} = F_{u,k} / b_V * L/4 + g * L_V * [2 L – L_V] / 8$

$M_{c,Rk,B}$	characteristic bending moment at internal support (kNm/m)
$F_{u,k}$	characteristic load in kN (including preload)
b_V	width of the test specimen (here: b_V = 1,20 m)
L_V	length of the test specimen (here: L_V = 2,40 m)
L	span length (here: L = 2,00 m)

g self weight of the test specimen according to table 3

The self weight of the specimen is composed of the liner tray and the cladding profile

The detailed test evaluation is presented in the annex. The main results are:

s_1	ultimate span moment $M_{c,Rk,F}$ (kNm/m)			
Mm	JID 110-0,75	JID 110-1,00	JID 160-0,75	JID 160-1,00
621	4,09	6,88	5,83	9,63
1242	2,96	5,47	3,98	7,40
1863	2,97	5,65	3,86	7,44
2000[1)]	2,79	5,17	3,04	6,85

1) Tests without outer cladding

Table 5: Test results (characteristic bending moment at support) of the internal support tests

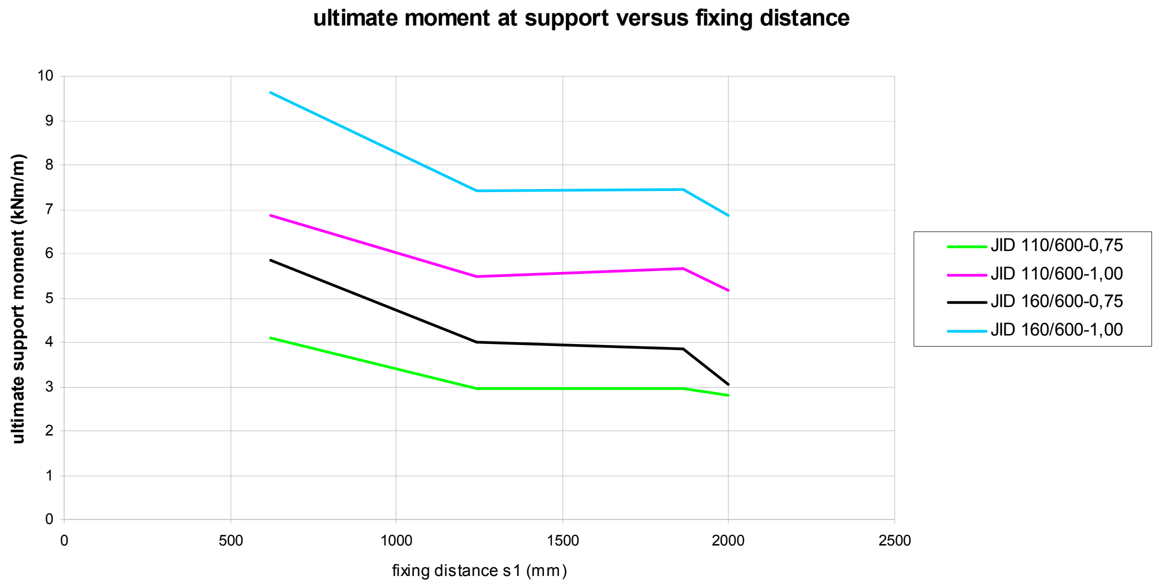

Fig. 14: Graphic view of the test results: characteristic bending moment at support depending of the fixing distance s_1

Related presentation without dimensions:

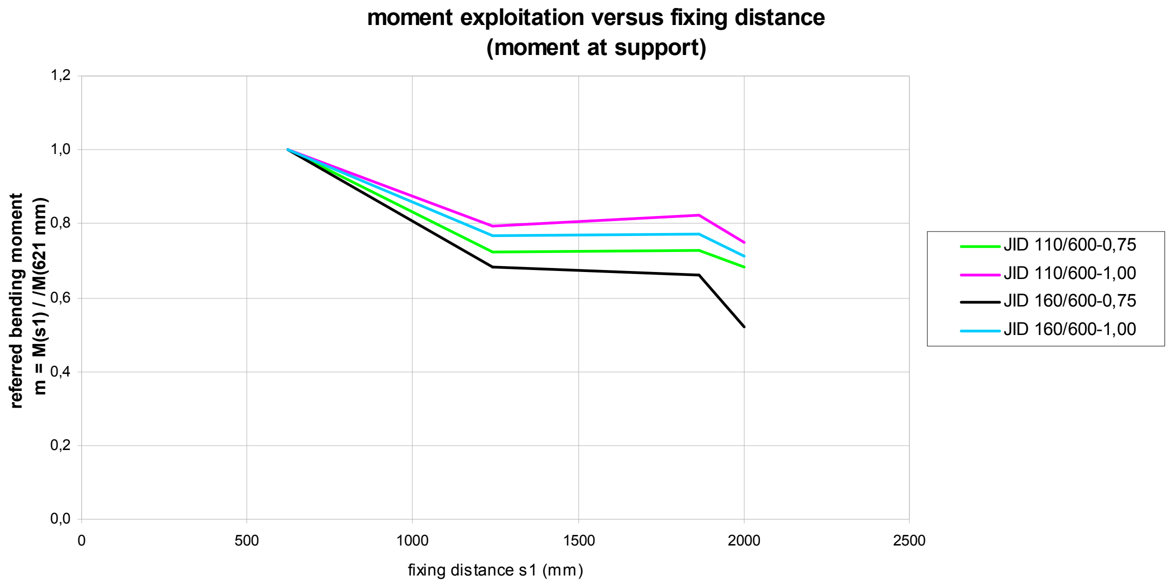

Fig. 15: Graphic view of the test results: characteristic bending moment at support depending of the fixing distance s_1

5. References

[1] Deliverable D 2.3: Test report. Liner trays. 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

[3] EN 10346: Continuously hot-dip coated steel flat products for cold forming – Technical delivery conditions

Annex: Detailed test evaluation