GRISPE

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

Test report

Liner Trays

Main Part

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Guidelines and Recommendations for Integrating Specific Profiled Steels sheets in the Euro-codes (GRISPE)

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Content

1 Preliminary remarks

Versuchsanstalt für Stahl, Holz und Steine of the Karlsruhe Institute of Technology (KIT) investigated the load-bearing capacity of liner trays with varying distance s_1 (fixation of the upper flange) for the research project “Guidelines and Recommendations for Integrating Specific Profiled Steels sheets in the Eurocodes (GRISPE)” co-funded under the Research Fund for Coal and Steel. The trapezoidal sheets, liner trays and spacer profiles were produced by Joris Ide (France). The test program was specified in the deliverable D2.2 “Test program definition”.

2 Object of testing

The tested liner trays specimens manufactured by Joris Ide consist of steel sheeting according to EN 10346:2009, which are formed to liner trays and trapezoidal sheets using the following section heights and overall widths by roll-forming:

Type of profile	Steel grade according to EN 10346:2009	Height [mm]	Width [mm]	Thickness [mm]
JI D_110-600SR	S320GD	110	600	0.75 and 1.00
JI D_160-600SR	S320GD	160	600	0.75 and 1.00
JI D_35-207-1035	S320GD	35	207	0.63 and 0.75

Table 1: Section heights and overall widths of the different tested profiles

The specimens for the single span tests and the internal support tests consists of a full and two half liner trays which are fixed in the webs with self-drilling screws (SFS SL2-4,8x20) and a trapezoidal sheet perpendicular to the liner trays which is fixed with the upper flange in the distance s_1. The specimens for the double span tests consists of a full and two half liner trays which are fixed in the webs with self-drilling screws (SFS SL2-4,8x20) and a distance profile (Z-profile or omega profile with height h = 50 mm or h = 200 mm) perpendicular to the liner trays which is fixed with the upper flange. A trapezoidal sheet parallel to the liner trays which is fixed with the distance profile builds the outer cladding.

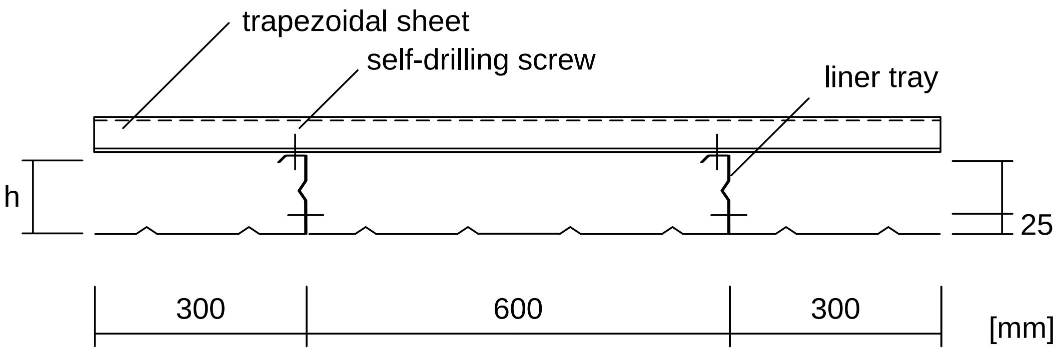

Fig. 1: Cross section of the test specimens for single span positive bending tests (SSP) and internal support tests for uplift loading (IS-W)

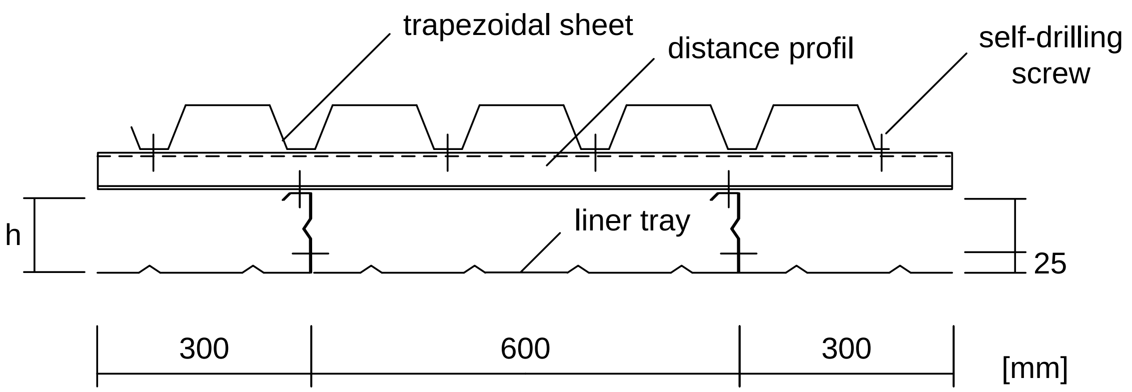

Fig. 2: Cross section of the test specimens for double span positive bending tests (DSP)

The nominal cross-section geometry of the tested profiles is given in annex A in figure A.1, figure A.2 and figure A.3. Detailed drawings of the specimens are given in Deliverable 2.2 Test specimens Rev03.

3 Scope of testing

The test performances for determination of the resistance values for bending and web crippling for liner trays with varying distance s_1 (fixation of the upper flange) were done according to EN 1993-1-3:2010. The tests performed are listed in table 2 as follows. In addition, tensile tests according to EN 6892-1:2009 on specimens taken from the sheeting were performed to determine of the material properties. Furthermore the profile geometry was measured.

Type of test	Profile	Nominal thick-ness [mm]	Span [mm]	Distance s_1 [mm]	Distance profile	Number of tests
Single span test, positive bending	JI D_110-600SR	0.75 and 1.00	6000	621	-	4
				1242	-	5
				1863	-	4
				-	-	4*)
	JI D_160-600SR	0.75 and 1.00		621	-	4
				1242	-	5
				1863	-	4
				-	-	4*)
Internal support, load case uplift loading	JI D_110-600SR	0.75 and 1.00	2000	621	-	4
				1242	-	4
				1863	-	4
				-	-	2*)
	JI D_160-600SR	0.75 and 1.00		621	-	4
				1242	-	4
				1863	-	4
				-	-	2*)
Double span test, positive bending	JI D_110-600SR	0.75	2x 4000	1863	Z-profile h=50mm	2
					Z-profile h=200mm	2
					Omega-profile h=50mm	2
					Omega-profile h=200mm	2
					Z-profile h=50mm	1*)

*) without trapezoidal sheet

Table 2: Tests performed

4 Test performance and results

4.1 General remarks

The test specimens were delivered May 11th (delivery 1), July 15th 2015 (delivery 2) and 17th December (delivery 3). The tests were performed using calibrated testing machines of the Versuchsanstalt für Stahl, Holz und Steine (KIT). The specimens are all described by the following system:

System:	XXX – XXX – XXX – XXXX – X
First block (three char.):	Type of test
	SSP = single span test, positive bending
	IS-W = internal support test for load case “uplift loading”
	DSP = double span test, positive bending
Second block (three char.):	height of the profile [mm]
Third block (three char.):	Sheet thickness of the liner tray
	75 = 0.75 mm
	100 = 1.00 mm
Fourth block: (three or four char.)	distance s_1 [mm] (block is cancelled by DSP tests)
Fifth block (one char.):	Test Number (running)

4.2 Single span tests

For the determination of the characteristic values of the mid-span moment resistance, single span tests for load case “gravity loading” (positive bending) were performed with uniformly distributed load simulated by four line loads. The tests performed are shown in table 2. The length of all liner tray specimens were l_v = 6400 mm. The overhang of each liner tray was 200 mm. The load was introduced into the trapezoidal outer sheet via transverse steel sections and timber blocks. Transverse ties prevented the profiles from spreading. At the end supports timber blocks were used to avoid local deformation. The deflections were measured continuously in mid-span by three trip wire displacement sensors, the deflections were measured under the bottom flanges, see figure B.1 in annex B. The structure of the specimens and the static systems are given in annex B. The load was applied deflection-controlled with a speed of 20 mm/min. The load was measured continuously using a load cell with a maximum capacity of 50 kN. The displacement and the load measured were visualized as load-deflection curve.

In all single span tests a non-linear load-deflection behaviour appeared until the failure load was reached. Failure occurred by local buckling of the upper flange in the span between the fixation of the upper flange. The results of the single span tests are shown in table 3. The load F_{max} indicates the failure load including preload, but without self-weight of the test specimen. Annex B shows the experimental setup, photos from the tests and the load deflection-curve.

Test	Span [mm]	t_N Liner tray [mm]	Measured t_N incl. zinc coating [mm]		Preload [kN]	F_{max} [kN]
			Liner tray	Trapezoidal sheet		
SSP-110-075-621-1	6000	0.75	0.725	0.650	0.73	5.00
SSP-110-075-621-2			0.724	0.645		4.74
SSP-110-075-1242-1			0.731	0.640		4.02
SSP-110-075-1242-2*)			0.723	0.648		4.74
SSP-110-075-1242-3*)			0.726	0.653		4.24
SSP-110-075-1863-1			0.734	0.643		3.76
SSP-110-075-1863-2*)			0.717	0.651		4.18
SSP-110-075-X-1*)			0.721	-	0.59	4.07 [b)]
SSP-110-075-X-2**)			0.722	-		3.80 [b)]
SSP-110-100-621-1	6000	1.00	-	0.643	0.73	10.12
SSP-110-100-621-2			0.984	0.641		9.60
SSP-110-100-1242-1			0.985	0.633		8.89
SSP-110-100-1242-2*)			0.980	0.645		9.14
SSP-110-100-1863-1			0.986	0.640		8.37
SSP-110-100-1863-2*)			0.974	0.646		8.51
SSP-110-100-X-1*)			0.981	-	0.59	8.60 [b)]
SSP-110-100-X-2*)			0.982	-		8.77 [b)]
SSP-160-075-621-1	6000	0.75	0.727	0.644	0.73	7.87
SSP-160-075-621-2			0.730	0.642		7.75
SSP-160-075-1242-1			0.724	0.645		5.87
SSP-160-075-1242-2*)			0.678	0.637		5.00
SSP-160-075-1242-3**)			0.725	0.632		5.10
SSP-160-075-1863-1			0.724	0.641		4.64
SSP-160-075-1863-2*)			0.728	0.652		4.84
SSP-160-075-X-1**)			0.722	-	0.59	4.25 [b)]
SSP-160-075-X-2**)			0.732	-		4.33 [b)]
SSP-160-100-621-1	6000	1.00	0.989	0.636	0.73	14.84
SSP-160-100-621-2			0.980	0.651		16.28
SSP-160-100-1242-1			0.991	0.666		12.18
SSP-160-100-1242-2*)			0.990	0.648		11.63
SSP-160-100-1863-1			0.994	0.635		9.69
SSP-160-100-1863-2*)			0.989	0.647		9.67
SSP-160-100-X-1*)			0.972	-	0.69	10.64 [a)]
SSP-160-100-X-2*)			0.972	-	0.67	9.47 [b)]

*) delivery 2, **) delivery 3, a) load distribution in the lower flange, b) load distribution in the upper flange

Table 3: Results of single span tests (SSP)

4.3 Internal support tests

Instead of extensive investigations of the intermediate support area of continuous beams, internal support tests for load case “uplift loading” were performed. The tests performed are shown in table 2. Loading was applied in mid-span via bolts M10 and steel plates in the lower flange of the liner trays. Transverse ties prevented the profiles from spreading. At the supports the liner trays were pivoted on timber blocks. The length of all liner tray specimens were l_v = 2400 mm. The overhang of each liner tray was 200 mm. The deflections were measured continuously in mid-span by two trip wire displacement sensors. The deflections were measured continuously at the load applying transverse steel beam. The structure of the specimens and the static systems are given in annex C.

The load was applied deflection-controlled with a speed of 3 mm/min to 6 mm/min, the speed was increased to 10 mm/min after the first peak of the load. The external load was measured continuously using a calibrated load cell. In all internal support tests an approximately linear elastic load-bearing behaviour appeared until failure load was reached. Failure occurred by buckling of the upper flange of the liner tray in the middle of the span. The results of the internal support tests are shown in table 4. The load F_{max} indicates the failure load including preload, but without self-weight of the test specimen. The measured nominal thickness including zinc coating was always measured at the middle liner tray. Annex C shows the test setup, photos of the tests and the load deflection-curves for load case.

Test	Span [mm]	t_N [mm]	Measured t_N incl. zinc coating [mm]		Preload [kN]	F_{max} [kN]
			Liner tray	Trapezoidal sheet		
IS-W-110-075-621-1			0.721	0.637		10.16
IS-W-110-075-621-2			0.727	0.642		10.75
IS-W-110-075-1242-1			0.725	0.640		8.04
IS-W-110-075-1242-2*)	2000	0.75	0.715	0.639	1.10	6.99 a)
IS-W-110-075-1863-1			0.722	0.649		7.74
IS-W-110-075-1863-2*)			0.723	0.639		7.34
IS-W-110-075-X-1*)			0.717	-		7.15
IS-W-110-100-621-1			0.992	0.636		17.64
IS-W-110-100-621-2			0.991	0.648		17.71
IS-W-110-100-1242-1			0.995	0.764		14.56
IS-W-110-100-1242-2*)	2000	1.00	0.976	0.645	1.10	13.46 a)
IS-W-110-100-1863-1			0.989	0.769		14.68
IS-W-110-100-1863-2*)			0.978	0.639		14.29
IS-W-110-100-X-1*)			0.981	-		13.30
IS-W-160-075-621-1			0.715	0.639		13.97
IS-W -160-075-621-2			0.725	0.642		15.39
IS-W-160-075-1242-1			0.725	0.649		10.69
IS-W-160-075-1242-2**)	2000	0.75	0.720	0.630	1.10	9.44
IS-W-160-075-1863-1			0.732	0.649		10.42
IS-W-160-075-1863-2**)			0.727	0.650		9.06
IS-W-160-075-X-1**)			0.731	-		7.79
IS-W-160-100-621-1			0.992	0.648		24.61
IS-W-160-100-621-2			0.989	0.644		25.04
IS-W-160-100-1242-1			0.990	0.644		19.66
IS-W-160-100-1242-2*)	2000	1.00	0.978	0.631	1.10	17.64
IS-W-160-100-1863-1			0.994	0.638		20.20
IS-W-160-100-1863-2*)			0.986	0.638		17.31
IS-W-160-100-X-1*)			0.988	-		16.96

*) delivery 2, **) delivery 3, a) screw hole in the middle of the span

Table 4: Results of internal support tests (IS-W)

4.4 Double span tests

The double span tests with outer cladding parallel to the liner trays and the spacer profiles were executed to study the influence of moment redistribution after local buckling of the intermediate support and the composite effect which is created by the shear connection be-

tween outer cladding and liner tray. The tests were performed for the load case “wind pressure”; the uniformly distributed load was represented by two line loads in each span. The load position follows the regulations in EN 1993-1-3. The tests performed are shown in table 2. The length of all liner tray specimens were l_v = 8400 mm and the nominal thickness t_N = 0.75 mm. The overhang of each liner tray was 200 mm. The load was introduced into the distance profiles via transverse steel sections. Transverse ties prevented the profiles from spreading. At the end supports timber blocks were used to avoid local deformation. The overhang of each liner tray was 200 mm. The deflections were measured continuously in each span and at the mid-support by each two trip wire displacement sensors, the deflections were measured under the bottom flanges (span) and at the distance profiles (mid-support), see figure D.1 in annex D. The structure of the specimens and the static systems are given in annex D. The load was applied deflection-controlled with a speed of 10 mm/min. The load was measured continuously using a load cell with a maximum capacity of 100 kN. The displacement and the load measured were visualized as load-deflection curve.
In all double span tests a non-linear load-deflection behaviour appeared until the failure load was reached. Failure occurred by local buckling of the trapezoidal sheet in one of the two spans after failure of the liner tray by web-crippling under the distance profiles and at mid-support. The results of the double span tests are shown in table 5. The load F_{max} indicates the failure load including preload, but without self-weight of the test specimen. Annex D shows the experimental setup, photos from the tests and the load deflection-curve.

Test	Span [mm]	Distance profile	Measured t_N incl. zinc coating [mm]			Preload [kN]	F_{max} [kN]
			Liner tray	Distance profile	Trapezoidal sheet		
DSP-110-075-1	2x4000	Z - profile h = 50 mm	0.73	1.54	0.65	1.26 (G2) And 0.63 (G3&G4)	22.08
DSP-110-075-2			0.74	1.56	0.66		21.18
DSP-110-075-3		Omega - profile h = 50 mm	0.74	1.54	0.66		25.97
DSP-110-075-4			0.72	1.49	0.64		27.39
DSP-110-075-5		Z - profile h = 200 mm	0.75	1.55	0.64		20.76
DSP-110-075-6*)			0.73	1.54	0.65		22.66
DSP-110-075-7		Omega - profile h = 200 mm	0.74	1.55	0.65		25.33
DSP-110-075-8			0.72	1.48	0.64		26.12
DSP-110-075-9**)		Z - profile h = 50 mm	0.74	1.48	-		16.57

*) Z-profiles turned around in one span, **) Z-profiles in the middle of each span turned around

Table 5: Results of double span tests (DSP)

4.5 Measurement of the profile geometry

The dimensions of the different profiles (JI D_110-600SR, JI D_160-600SR and JI D_35-207-1035) were determined. The results are documented in annex E. In addition the sheet thickness of the liner tray test specimens for delivery two were measured. The results are documented in annex E, too.

4.6 Material properties

For the determination of the material properties, 3 specimens per sheet and per thickness were worked out, from coupons which were cut out the tested profiles, for tensile tests according to EN 6892-1:2009 with the specimen shape 2 according to EN 6892-1:2009 table B.1. The determination of the yield strength $R_{p0.2}$ and the tensile strength R_m was based upon the measured sheet thickness exclusive of zinc coating. The results of the tensile tests are given in table 6 and table 7.

Profile	Nominal thickness t_N [mm]	Core thickness t_K [mm]	Yield strength $R_{p0,2}$ [N/mm²]	Tensile strength R_m [N/mm²]	Elongation at fracture $A_{L=80mm}$ [%]
JI D_110-600SR Delivery 1	0.75	0.70	351	463	24.4
		0.69	353	464	24.7
		0.69	352	463	24.6
	1.00	0.97	335	402	26.8
		0.96	340	401	27.6
		0.96	337	403	27.3
JI D_160-600SR Delivery 1	0.75	0.70	334	400	27.7
		0.70	334	400	27.7
		0.70	334	400	28.0
	1.00	0.97	352	383	29.7
		0.96	353	383	29.6
		0.96	356	383	29.6

Table 6: Results of tensile tests (delivery 1)

Profile	Nominal thickness t_N [mm]	Core thickness t_K [mm]	Yield strength $R_{p0,2}$ [N/mm²]	Tensile strength R_m [N/mm²]	Elongation at fracture $A_{L=80mm}$ [%]
JI D_110-600SR Delivery 2	0.75	0.69	355	463	25.5
		0.69	353	463	25.3
		0.69	353	463	25.7
	1.00	0.96	331	393	27.7
		0.96	337	393	29.0
		0.95	337	394	28.7
JI D_160-600SR Delivery 2	0.75*)	0.72	355	467	25.4
		-	-	-	-
		-	-	-	-
	0.75**)	0.64	360	469	24.8
		0.66	354	465	24.9
		0.64	361	469	24.3
	1.00	0.95	337	394	27.9
		0.95	333	395	28.5
		0.95	334	392	27.8
JI D_110-600SR Delivery 3	0.75	0.69	351	461	26.6
		-	-	-	-
		-	-	-	-
JI D_160-600SR Delivery 3	0.75	0.70	348	410	29.1
		0.70	348	411	28.7
		0.70	347	411	28.9

*) coupons of SSP-160-075-1863-2, **) coupons of SSP-160-075-1242-2

Table 7: Results of tensile tests (delivery 2 and delivery 3)

5 Summary

For the research project “Guidelines and Recommendations for Integrating Specific Profiled Steels sheets in the Eurocodes (GRISPE)” co-funded under the Research Fund for Coal and Steel the Versuchsanstalt für Stahl, Holz und Steine of the Karlsruhe Institute of Technology (KIT) made experimental investigations according to EN 1993-1-3:2010 on the load-bearing capacity of liner trays. Also tensile tests according to EN 6892.1:2009 and profile geometry measurements were accomplished.

In chapter 2 the test specimens are described with regard to application, geometry and material. Chapter 3 reflects the scope of testing. The description of the test set-up, the test performance and the documentation of the test results are given in chapter 4.