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

Test report

Curved Profiles

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 curved trapezoidal and corrugated sheets 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 curved corrugated sheets were produced by Bacacier (France) and the curved trapezoidal sheets by Arcelor Mittal Construction France. The test program was specified in the deliverable D2.2 “Test program definition”.

2 Object of testing

The tested specimens manufactured by Bacacier and Arcelor Mittal consist of steel sheeting according to EN 10346:2009, which are formed to curved corrugated sheets and curved 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]
Bacacier 18/76	S320GD	18	912	0.75 and 1.00
Arcelor Mittal 39/333	S320GD	39	1000	0.63 and 1.00

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

The nominal cross-section geometry of the tested profiles is given in annex A in figure A.1 and figure A.2.

3 Scope of testing

The test performances for determination of the resistance values for bending were done according to EN 1993-1-3:2010. In addition to verify the load-bearing behaviour under combined bending moment and axial compression eight tests were performed with horizontal supports. The tests performed are listed in table 2 as follows. The specifications of the used parameters in table 2 are explained in figure 1. In addition, tensile tests according to EN 6892-1:2009 on specimens taken from the sheeting were performed to determine the material properties. Furthermore the profile geometry was measured.

Type of test	Profile	R [m]	b [mm]	Span L [mm]	s [mm]	f [mm]	α [°]	Number of tests
Single span positive bending test	18/76 t_N = 0.63 mm	∞	2200	2000	2200	0	0	3
		20.0	2201			30	6.31	2
		10.0	2204			61	12.63	2
		4.0	2229			154	31.92	2
	18/76 t_N = 1.00 mm	∞	3200	3000	3200	0	0	1
		20.0	3203			64	9.18	4
		10.0	3214			129	18.41	3
		4.0	3292			334	47.16	3
	39/333 t_N = 0.63 mm	∞	3200	3000	3200	0	0	3
		20.0	3203			64	9.18	2
		10.0	3214			129	18.41	2
		6.0	3239			217	30.93	3
	39/333 t_N = 1.00 mm	∞	4200	4000	4200	0	0	2
		20.0	4208			111	12.05	2
		10.0	4232			223	24.24	2
		6.0	4291			380	40.98	2
Single span positive bending test with horizontal support	39/333 t_N = 0.63 mm	6.0	3239	3000	3200	217	30.93	2
		6.0	4291	4000	4200	380	40.97	3
		6.0	5300	5000	5129	576	50.61	3

Table 2: Tests performed

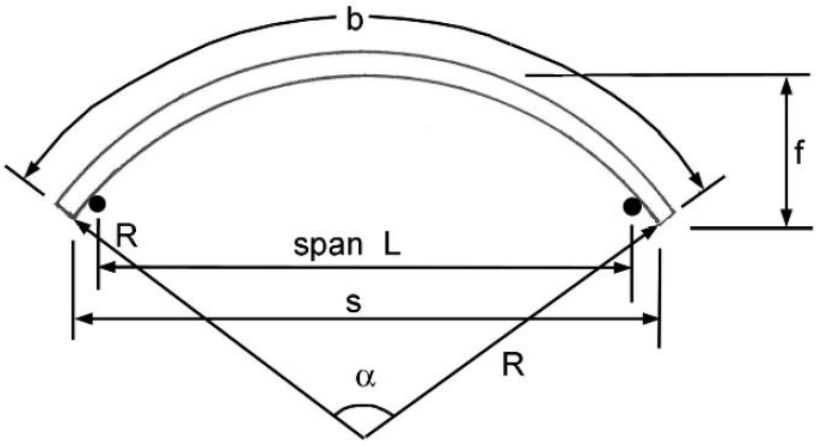

Figure 1: Curved profiles

4 Test performance and results

4.1 General remarks

The test specimens were delivered April 21th (corrugated sheets) and June 15th (trapezoidal sheets).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:	SSP – X - XX – XXX – XXX – X
First block (one char.):	Horizontal support
Second block (two char.):	height of the profile [mm]
Third block: (one to three char.)	arch stitch [mm]
Fourth block (three char.): (three char.)	Sheet thickness [1/100 mm]
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. In addition for the verification of the load-bearing behaviour under combined bending moment and axial compression single span tests with horizontal support for load case “gravity loading” (positive bending and compression) were performed with uniformly distributed load simulated by four line loads. The overhang of each profile was between 100 mm and 150 mm. The load was introduced into the valleys of the corrugated sheets or the bottom flanges of the trapezoidal sheets via transverse steel sections and timber blocks. The transverse steel sections were clamped with the profile. In order to reduce the friction between the transverse steel beams at the supports of the load distribution system oil was used. The deflections were measured continuously in mid-span by two trip wire displacement sensors, the deflections were measured under the bottom flanges. The structure of the specimens and the static systems are given in annex B. The load was applied deflection-controlled with a speed of 6 mm/min to 15 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 of the trapezoidal sheets (profile 39/333) and the tests of the corrugated sheets (profile 18/76) with a nominal thickness of $t_N = 0.63$ mm a non-linear load-

deflection behaviour appeared until the failure load was reached. Failure occurred by local buckling of the upper flange (trapezoidal sheets) or the crest (corrugated sheets) in the span. Failure by plastic deformation occurred in all tests of the corrugated sheets (profile 18/76) with a nominal thickness of t_N = 1.00 mm, none F_{max} value is determined in the result table. The results of the single span tests without horizontal support are shown in table 3 and 4 and in table 5 for single span tests with horizontal support. 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 [mm]	b [mm]	Measured t_N incl. zinc coating [mm]	Measured height f [mm]		Measured width b [mm]	Preload [kN]	F_{max} [kN]
SSP-18-0-063-1[1)]	2000	0.63	2200	0.57	0	0	894	0.29	3.71
SSP-18-0-063-2[1)]				0.56	0	0	895		4.07
SSP-18-0-063-3[1)]				0.56	0	0	890		3.91
SSP-18-30-063-1[1)]			2201	0.59	40	47	890	0.29	3.97
SSP-18-30-063-2[1)]				0.55	40	48	892		3.93
SSP-18-61-063-1[1)]			2204	0.56	45	56	888		4.11
SSP-18-61-063-2[1)]				0.56	48	60	890		4.01
SSP-18-154-063-1[2)]			2229	0.56	120	115	890	0.49	4.98
SSP-18-154-063-2[2)]				0.55	120	120	895		4.86
SSP-18-0-100-1[1)]	3000	1.00	3200	1.00	0	0	887	0.35	-
SSP-18-0-100-2				-	-	-	-	-	-
SSP-18-64-100-1[2)]			3203	0.99	75	60	885	0.49	-
SSP-18-64-100-2[2)]				0.99	70	70	885		-
SSP-18-64-100-3[2)]				0.99	64	60	885		-
SSP-18-64-100-4[2)]				0.99	60	65	885		-
SSP-18-129-100-1[2)]			3214	1.01	110	120	885	0.49	-
SSP-18-129-100-2[2)]				1.00	110	125	885		-
SSP-18-129-100-3[2)]				0.99	90	85	885		-
SSP-18-334-100-1[2)]			3292	1.00	320	300	885	0.80	-
SSP-18-334-100-2[2)]				1.00	325	295	885		-
SSP-18-334-100-3[2]				1.00	315	300	885		-

1) test setup for flat profiles, 2) test setup for curved profiles, *) test setup for curved profiles without oil at supports of the load distribution system

Table 3: Results of single span tests of profile 18/76

Test	Span [mm]	t_N [mm]	b [mm]	Measured t_N incl. zinc coating [mm]	Measured height f [mm]		Measured width b [mm]	Preload [kN]	F_{max} [kN]
SSP-39-0-063-1[1)]	3000	0.63	3200	0.66	0	0	668	0.43	2.09
SSP-39-0-063-2[1)]				0.65	0	0	660		2.03
SSP-39-0-063-3[2)]				0.65	0	0	670	0.40	1.85
SSP-39-64-063-1[1)]			3203	0.66	37	34	660	0.43	1.92
SSP-39-64-063-2[1)]				0.66	34	32	663		1.96
SSP-39-129-063-1[1)]			3214	0.65	116	116	663	0.48	1.84
SSP-39-129-063-2[1)]				0.65	116	120	661		1.85
SSP-39-217-063-1[2)]			3239	0.64	205	200	670	0.49	1.61
SSP-39-217-063-2[2)]				0.66	205	205	670		1.56
SSP-39-217-063-3[2)]				0.68	210	210	668		1.65
SSP-39-0-100-1[1)]	4000	1.00	4200	1.02	0	0	665	0.71	2.80
SSP-39-0-100-2[1)]				1.01	0	0	668		2.81
SSP-39-111-100-1[1)]			4208	1.01	74	82	668		2.78
SSP-39-111-100-2[1)]				1.02	74	80	668		2.72
SSP-39-223-100-1[2)]			4232	1.02	190	190	670	0.49	2.81
SSP-39-223-100-2[2)]				1.03	190	190	670		2.82
SSP-39-380-100-1[2)]			4291	1.03	320	327	670	0.49	2.82
SSP-39-380-100-2[2)]				1.04	325	315	670		2.85

1) test setup for flat profiles, 2) test setup for curved profiles

Table 4: Results of single span tests of profile 39/333

Test	Span [mm]	Measured t_N incl. zinc coating [mm]	Measured height f [mm]		Measured width b [mm]	Preload [kN]	F_{max} [kN]
SSP-H-39-217-063-1[1)]	3000	0.66	200	210	670	0.49	9.12
SSP-H-39-217-063-2[1)]		0.66	205	210	670		8.95
SSP-H-39-380-063-1[1)]	4000	0.66	330	350	670	0.49	9.49
SSP-H-39-380-063-2[1)]		0.66	340	350	670		11.43
SSP-H-39-380-063-3[1)]		0.66	335	345	370		11.03
SSP-H-39-576-063-1[1)]	5000	0.65	460	465	665	0.49	5.67
SSP-H-39-576-063-2[1)]		0.67	450	455	668		5.17
SSP-H-39-576-063-3[1)]		0.67	460	465	665		6.83

1) test setup for curved profiles with horizontal support

Table 5: Results of single span tests of profile 39/333 with horizontal support

4.3 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 trapezoidal sheets or from coupons which were delivered from Bacacier for the corrugated sheets, 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.

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 $A_{L=80mm}$ [%]
18/76	0.63	0.53	330	456	26.2
		0.53	329	457	26.0
		0.52	329	456	25.4
	1.00	0.99	342	387	29.3
		1.00	346	387	27.6
		0.99	358	392	27.9
39/333	0.63	0.58	406	430	27.6
		0.58	411	430	26.4
		0.58	408	431	27.0
	1.00	0.96	379	425	24.7
		0.96	384	427	24.5
		0.95	382	426	25.4

Table 6: Results of tensile tests

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 curved trapezoidal and corrugated sheets. 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.