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

Test report

Interlocking planks

Main Part

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Guidelines and Recommendations for Integrating Specific Profiled Steel 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 interlocking plank profiles for the research project "Guidelines and Recommendations for Integrating Specific Profiled Steel sheets in the Eurocodes (GRISPE)" co-funded under the Research Fund for Coal and Steel. The profiles were produced by Bacacier (France) and Joris Ide (France). The test program was specified in the deliverable D 4.2 "Test program definition".

2 Object of testing

The tested profiles from Bacacier and Joris Ide consist of galvanized steel sheeting according to EN 10346:2009, which are formed to profiles with 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]
Cladeo 300	S320GD	25	300	0.75 and 1.00
Zephir 300	S320GD	30	300	0.75 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.1 to A.2.

3 Scope of testing

The test performances for determination of the resistance values for bending, shear and web-crippling 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	Thickness [mm]	Span [mm]	Number of tests		
			Cladeo	Zephir	Zephir with end rein-forcement
Single span test (pressure)	0.75	1500	3	3	3
	1.00		3	3	3
Single span test (suction)	0.75	1500	1	3	3
	1.00		3	3	3
Double span test (pressure)	0.75	1000	1	1	1
	0.75	2000	3	3	3
	1.00		3	3	3
	0.75	2500	3	3	3
	1.00		3	3	3
Double span test (suction)	0.75	1000	3	3	3
	1.00		-	1	-
	0.75	2000	3	3	3
	1.00		3	3	3
	0.75	2500	3	3	3
	1.00		3	3	3
End support test (pressure)	0.75	410	6	6	-
	1.00		6	6	-

Table 2: Tests performed

4 Test performance and results

4.1 General remarks

The test specimens were delivered October 26th and December 8th 2015. The tests were performed using calibrated testing machines of the Versuchsanstalt für Stahl, Holz und Steine of the Karlsruhe Institute of Technology (KIT). The bending tests were performed in a vacuum chamber. The end support tests were performed on a test setup with a hydraulic cylinder. The specimens are all described by the following system:

Single Span bending test:

System: SSX – XX – XXX – X

First block (one char.): Type of test

P = pressure test

N = suction test

Second block (one or two char.): Type of profile

C = Cladeo

Z = Zephir

ZR = Zephir with end reinforcement

Third block (three char.): Sheet thickness

075 = 0.75 mm

100 = 1.00 mm

Forth block (one char.): Test number (running)

Double Span bending test:

System: DSX – XX – X - XXX – X

First block (one char.): Type of test

P = pressure test

N = suction test

Second block (one or two char.): Type of profile

C = Cladeo

Z = Zephir

ZR = Zephir with end reinforcement

Third block (one char.): Span

1 = 1000 mm

2 = 2000 mm

3 = 2500 mm

Fourth block (three char.): Sheet thickness

075 = 0.75 mm

100 = 1.00 mm

Fifth block (one char.): Test number (running)

End support test:

System: ES – XX – XXX – XX - X

First block (one or two char.): Type of profile

C = Cladeo

Z = Zephir

ZR = Zephir with end reinforcement

Second block (three char.): Sheet thickness

	075 = 0.75 mm
	100 = 1.00 mm
Third block (two char.):	distance u [mm]
Forth 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 the load cases “wind pressure” and “wind suction” were performed; the uniformly distributed load was represented by a surface load. The tests performed are shown in table 2. Each test consists of five specimens. The support width in all tests was 40 mm. The deflections were measured continuously in span and at one end support by each three trip wire displacement sensors in vertical direction and by each one displacement sensor in horizontal direction (only by wind suction tests), the position of the displacement sensors are documented in annex B (wind pressure tests) and annex C (wind suction tests). The structure of the specimens and the static systems are given in annex B (wind pressure tests) and annex C (wind suction tests). To avoid local buckling the small edge of the outer profile was reinforced with a aluminium U-profile 40x40x5.

The load was applied by creating a under pressure. The load was measured continuously using each two load cells with a maximum capacity of 20 kN at each support. The displacements and the loads measured were visualized as load-deflection curves.

In all single span tests a non-linear load-deflection behaviour appeared until the failure load was reached. Failure occurred in one test (SSN-Z-100-1) through dislocation of the non-fixed edge of the plank profile in all other tests (pressure and suction) failure occurred through local buckling of the compressed flanges of the plank profiles. The results of the single span tests are listed in the following tables 3 and 4. The load F_{tot} indicates the failure load but without self-weight of the test specimens. Annex B (wind pressure tests) and annex C (wind suction tests) shows the experimental setup, photos from the tests and the load deflection-curve of the wind pressure tests.

Test	Span [mm]	Length of specimen [mm]	Nominal thickness [mm]	Measured thickness incl. zinc coating [mm]					F_{tot} [kN]
				1	2	3	4	5	
SSP-C-075-1	1500	1580	0.75	-	-	0.74	-	-	7.31
SSP-C-075-2				-	-	0.74	-	-	7.65
SSP-C-075-3				0.75	0.75	0.75	0.75	0.74	7.39
SSP-C-100-1			1.00	1,07	1.07	1.07	1.07	1.07	15.26
SSP-C-100-2				1,07	1.07	1.07	1.07	1.07	15.42
SSP-C-100-3				1.07	1.08	1.08	1.08	1.08	15.13
SSP-Z-075-1	1500	1580	0.75	0.76	0.75	0.75	0.75	0.75	10.04
SSP-Z-075-2				0.74	0.75	0.75	0.75	0.75	10.60
SSP-Z-075-3				0.74	0.75	0.74	0.77	0.75	10.61
SSP-Z-100-1			1.00	0.98	0.98	0.98	0.98	0.98	15.14
SSP-Z-100-2				0.97	0.98	0.98	0.98	0.98	15.42
SSP-Z-100-3				0.98	0.98	0.98	0.98	0.98	15.53
SSP-ZR-075-1	1500	1580	0.75	0.72	0.73	0.74	0.74	0.76	9.72
SSP-ZR-075-2				0.72	0.73	0.73	0.74	0.71	9.77
SSP-ZR-075-3				0.72	0.73	0.75	0.73	0.70	9.86
SSP-ZR-100-1			1.00	0.98	0.98	0.98	0.98	0.98	16.14
SSP-ZR-100-2				0.97	0.97	0.98	0.96	0.96	16.03
SSP-ZR-100-3				0.97	0.97	0.98	0.98	0.96	16.35

Table 3: Results of single span tests (pressure tests)

Test	Span [mm]	Length of specimen [mm]	Nominal thickness [mm]	Measured thickness incl. zinc coating [mm]					F_{tot} [kN]
				1	2	3	4	5	
SSN-C-075-1	1500	1580	0.75	0.74	0.74	0.74	0.73	0.74	11.18
SSN-C-075-2				-	-	-	-	-	-
SSN-C-075-3				-	-	-	-	-	-
SSN-C-100-1			1.00	1.07	1.02	1.05	1.05	1.05	17.25
SSN-C-100-2				1.07	1.07	1.06	1.07	1.02	15.09
SSN-C-100-3				1.02	0.98	0.98	0.98	0,97	15.60
SSN-Z-075-1	1500	1580	0.75	0.74	0.74	0.75	0.74	0,74	8.49
SSN-Z-075-2				0.76	0.74	0.74	0.73	0.74	10.23
SSN-Z-075-3				0.73	0.74	0.73	0.74	0.74	10.44
SSN-Z-100-1			1.00	0.97	0.97	0.97	0.98	0.99	16.84
SSN-Z-100-2				0.97	0.97	0.97	0.97	0.98	15.47
SSN-Z-100-3				0.97	0.98	0.97	0.98	0.97	15.93
SSN-ZR-075-1	1500	1580	0.75	0.75	0.74	0.75	0.70	0.70	8.22
SSN-ZR-075-2				0.74	0.74	0.74	0.74	0.74	8.69
SSN-ZR-075-3				0.75	0.74	0.72	0.74	0.73	9.08
SSN-ZR-100-1			1.00	0.98	0.96	0.93	0.93	0.93	16.13
SSN-ZR-100-2				0.92	0.92	0.93	0.94	0.98	14.30
SSN-ZR-100-3				0.90	0.90	0.97	0.97	0.96	15.11

Table 4: Results of single span tests (suction tests)

4.3 Double span tests

The double span tests were executed to study the influence of moment redistribution after local buckling of the intermediate support and the moment-reaction distribution. The tests were performed for the load cases “wind pressure” and “wind suction”; the uniformly distributed load was represented by a surface load. The tests performed are shown in table 2. Each test consists of five specimens. The support width in all tests was 40 mm. The deflections were measured continuously in each span and at the mid-support by each three trip wire displacement sensors in vertical direction and by each one displacement sensor in horizontal direction (only by wind suction tests), the position of the displacement sensors are documented in annex D (wind pressure tests) and annex E (wind suction tests). The structure of the specimens and the static systems are given in annex D (wind pressure tests) and

annex E (wind suction tests). The load was applied by creating a under pressure. The load was measured continuously using each two load cells with a maximum capacity of 10 kN at each support. The displacements and the loads measured were visualized as load-deflection curves.

In all double span tests a non-linear load-deflection behaviour appeared until the failure load was reached. In the wind pressure test failure occurred by local buckling of the compressed flanges. In the wind suction test failure occurred by local buckling of the compressed flanges (failure mode B) or dislocation of the non-fixed edge of the plank profile (failure mode DL). Results of the double span tests are shown in table 5 to table 9. The load F_{tot} indicates the failure load but without self-weight of the test specimen. Annex D (wind pressure tests) and annex E (wind suction tests) shows the experimental setup, photos from the tests and the load deflection-curves of the wind pressure tests.

Test	Span [mm]	Length of specimen [mm]	Nominal thickness [mm]	Measured thickness incl. zinc coating [mm]					F_{tot} [kN]
				1	2	3	4	5	
DSP-C-1-075-1	1000	2080	0:75	0.74	0.75	0.74	0.74	0.75	>30,00
DSP-C-2-075-1	2000	4080	0.75	0.73	0.73	0.73	0.74	0.74	12.81
DSP-C-2-075-2				0.73	0.73	0.74	0.74	0.74	12.66
DSP-C-2-075-3				0.73	0.73	0.73	0.73	0.73	12.59
DSP-C-2-100-1			1.00	1.06	1.06	1.08	1.07	1.07	29.66
DSP-C-2-100-2				1.07	1.06	1.07	1.08	1.07	26.78
DSP-C-2-100-3				1.07	1.07	1.06	1.07	1.08	26.02
DSP-C-3-075-1	2500	5080	0.75	0.74	0.74	0.74	0.74	0.74	9.75
DSP-C-3-075-2				0.74	0.74	0.74	0.74	0.74	10.02
DSP-C-3-075-3				0.73	0.74	0.75	0.74	0.74	10.06
DSP-C-3-100-1			1.00	1.07	1.09	1.09	1.09	1.08	19.78
DSP-C-3-100-2				1.07	1.07	1.09	1.08	1.09	20.10
DSP-C-3-100-3				1.07	1.07	1.08	1.09	1.09	20.68

Table 5: Results of double span tests (pressure tests) for Cladeo

Test	Span [mm]	Length of specimen [mm]	Nominal thickness [mm]	Measured thickness incl. zinc coating [mm]					F_{tot} [kN]
				1	2	3	4	5	
DSP-Z-1-075-1	1000	2080	0.75	0.74	0.75	0.76	0.75	0.75	>30.00
DSP-Z-2-075-1	2000	4080	0.75	0.76	0.76	0.76	0.76	0.75	18.54
DSP-Z-2-075-2				0.76	0.76	0.75	0.76	0.76	18.09
DSP-Z-2-075-3				0.75	0.75	0.76	0.75	0.76	18.94
DSP-Z-2-100-1			1.00	0.99	0.99	0.99	0.98	0.99	26.47
DSP-Z-2-100-2				0.98	0.98	0.98	0.98	0.98	26.74
DSP-Z-2-100-3				0.99	0.99	0.98	0.98	0.98	26.23
DSP-Z-3-075-1	2500	5080	0.75	0.76	0.75	0.75	0.75	0.75	13.13
DSP-Z-3-075-2				0.74	0.74	0.76	0.76	0.75	13.01
DSP-Z-3-075-3				0.74	0.74	0.74	0.74	0.73	12.54
DSP-Z-3-100-1			1.00	0.98	0.99	0.98	0.98	0.98	21.06
DSP-Z-3-100-2				0.98	0.97	0.98	0.97	0.99	21.45
DSP-Z-3-100-3				0.99	0.98	0.99	0.98	0.98	21.40
DSP-ZR-1-075-1	1000	2080	0.75	0.74	0.75	0.76	0.75	0.75	>30.00
DSP-ZR-2-075-1	2000	4080	0.75	0.74	0.73	0.73	0.73	0.75	18.00
DSP-ZR-2-075-2				0.73	0.75	0.76	0.75	0.75	17.72
DSP-ZR-2-075-3				0.73	0.73	0.73	0.75	0.75	18.94
DSP-ZR-2-100-1			1.00	1.00	1.00	1.00	1.00	1.00	26.01
DSP-ZR-2-100-2				1.00	1.00	0.99	1.00	1.00	25.60
DSP-ZR-2-100-3				1.00	0.98	0.99	0.99	1.00	25.61
DSP-ZR-3-075-1	2500	5080	0.75	0.73	0.74	0.74	0.72	0.73	13.00
DSP-ZR-3-075-2				0.75	0.73	0.76	0.74	0.73	13.48
DSP-ZR-3-075-3				0.73	0.75	0.73	0.72	0.75	13.62
DSP-ZR-3-100-1			1.00	0.99	0.99	0.96	0.98	0.98	19.88
DSP-ZR-3-100-2				0.98	0.98	0.98	0.99	0.98	19.85
DSP-ZR-3-100-3				0.99	1.00	0.98	0.99	0.98	19.85

Table 6: Results of double span tests (pressure tests) for Zephir

Test	Span [mm]	Length of specimen [mm]	Nominal thickness [mm]	Measured thickness incl. zinc coating [mm]					F_{tot} [kN]	Failure
				1	2	3	4	5		
DSN-C-1-075-1	1000	2080	0.75	0.75	0.74	0.74	0.74	0.73	28.35	B
DSN-C-1-075-2				0.74	0.74	0.74	0.75	0.76	27.81	
DSN-C-1-075-3				0.76	0.74	0.74	0.75	0.74	>30.00	-
DSN-C-2-075-1	2000	4080	0.75	0.74	0.73	0.74	0.74	0.73	13.90	B
DSN-C-2-075-2				0.74	0.73	0.74	0.74	0.74	14.06	
DSN-C-2-075-3				0.73	0.73	0.73	0.73	0.73	15.79	
DSN-C-2-100-1			1.00	1.07	1.06	1.08	1.08	1.08	28.83	B
DSN-C-2-100-2				1.07	1.08	1.08	1.07	1.07	27.15	
DSN-C-2-100-3				1.07	1.07	1.08	1.07	1.07	28.81	
DSN-C-3-075-1	2500	5080	0.75	0.74	0.74	0.72	0.73	0.73	7.19	DL
DSN-C-3-075-2				0.73	0.73	0.74	0.74	0.74	8.30	
DSN-C-3-075-3				0.74	0.74	0.74	0.74	0.75	8.63	
DSN-C-3-100-1			1.00	1.08	1.09	1.10	1.08	1.08	22.46	B
DSN-C-3-100-2				1.08	1.08	1.10	1.10	1.08	22.97	
DSN-C-3-100-3				1.07	1.07	1.07	1.07	1.07	23.09	

Table 7: Results of double span tests (suction tests) for Cladeo

Test	Span [mm]	Length of specimen [mm]	Nominal thickness [mm]	Measured thickness incl. zinc coating [mm]					F_{tot} [kN]	Failure
				1	2	3	4	5		
DSN-Z-1-075-1	1000	2080	0.75	0.74	0.74	0.74	0.74	0.74	>30.00	-
DSN-Z-1-075-2				0.74	0.75	0.73	0.75	0.74	>30.00	
DSN-Z-1-075-3				0.75	0.74	0.73	0.74	0.74	26.83	B
DSN-Z-1-100-1			1.00	1.07	1.07	1.07	1.07	1.07	>30.00	-
DSN-Z-2-075-1	2000	4080	0.75	0.75	0.74	0.74	0.74	0.73	17.67	B
DSN-Z-2-075-2				0.75	0.75	0.75	0.74	0.74	15.40	
DSN-Z-2-075-3				0.75	0.75	0.74	0.75	0.74	11.00	
DSN-Z-2-100-1			1.00	0.98	0.98	0.97	0.97	0.97	18.96	B
DSN-Z-2-100-2				0.98	0.98	0.97	0.97	0.98	21.08	
DSN-Z-2-100-3				1.01	0.98	0.99	0.99	0.98	20.27	
DSN-Z-3-075-1	2500	5080	0.75	0.75	0.74	0.75	0.75	0.75	5.63	B
DSN-Z-3-075-2				0.75	0.76	0.75	0.75	0.75	4.78	
DSN-Z-3-075-3				0.75	0.74	0.72	0.72	0.76	3.95	
DSN-Z-3-100-1			1.00	0.99	0.99	0.99	0.99	0.99	8.92	DL
DSN-Z-3-100-2				0.96	0.97	0.98	0.99	0.99	9.16	
DSN-Z-3-100-3				0.97	0.96	0.98	0.96	0.97	10.25	

Table 8: Results of double span tests (suction tests) for Zephir

Test	Span [mm]	Length of specimen [mm]	Nominal thickness [mm]	Measured thickness incl. zinc coating [mm]					F_{tot} [kN]	Failure
				1	2	3	4	5		
DSN-ZR-1-075-1	1000	2080	0.75	0.74	0.74	0.74	0.74	0.74	28.15	
DSN-ZR-1-075-2				0.74	0.72	0.73	0.73	0.74	26.36	
DSN-ZR-1-075-3				0.74	0.75	0.72	0.73	0.74	>30.00	-
DSN-ZR-2-075-1	2000	4080	0.75	0.74	0.73	0.77	0.74	0.74	13.16	
DSN-ZR-2-075-2				0.74	0.74	0.74	0.74	0.74	13.44	
DSN-ZR-2-075-3				0.75	0.74	0.74	0.74	0.75	11.64	
DSN-ZR-2-100-1			1.00	0.99	1.00	0.99	0.99	0.99	26.29	
DSN-ZR-2-100-2				0.98	0.97	0.98	0.99	0.98	27.16	
DSN-ZR-2-100-3				0.98	0.98	0.94	0.98	1.00	23.88	
DSN-ZR-3-075-1	2500	5080	0.75	0.75	0.73	0.73	0.72	0.75	12.02	
DSN-ZR-3-075-2				0.75	0.73	0.75	0.73	0.75	9.81	DL
DSN-ZR-3-075-3				0.74	0.72	0.74	0.72	0.75	12.06	
DSN-ZR-3-100-1			1.00	1.00	0.99	0.99	1.00	1.00	20.41	
DSN-ZR-3-100-2				1.00	1.01	1.05	1.00	1.00	19.99	B
DSN-ZR-3-100-3				0.96	0.96	0.97	0.97	0.97	20.18	

Table 9: Results of double span tests (suction tests) for Zephir with end reinforcement

4.4 End support tests

For the determination of the characteristics values of the end support resistance end support tests for load case “wind pressure” were performed. The tests performed are shown in table 2. Each test consists of three specimens. The load was applied via a transverse steel plate and a wooden beam with a width of b = 100 mm.

The profiles were prevented from spreading by transverse ties. At the tested end support a cutting edge (gradient of 1:20) is located. In the tests the value u (see annex F) was 40mm or 80 mm. The deflections were measured continuously at the transverse steel plate. The structure of the specimens and the static systems are given in annex F The load was applied deflection-controlled with a speed of 3 mm/min. The load was measured continuously using a calibrated load cell. Failure occurred by deformation of the webs (web-crippling) at the end supports followed by local buckling of the plank profiles under the load applying plate. The results of the end support tests are listed in table 10. The load F_{tot} indicates the failure load including preload but without self-weight of the test specimens. Annex F show the test setup, photos from the tests and the load-deflection curves.

Test	Span [mm]	Length of specimen [mm]	Nominal thickness [mm]	Measured thickness incl. zinc coating [mm]			value u [mm]	Pre-load [kN]	F_{tot} [kN]
				1	2	3			
ES-C-075-40-1	410	540	0.75	0.74	0.74	0.74	40	0.14	8.82*)
ES-C-075-40-2				0.74	0.74	0.74			10.32
ES-C-075-40-3				0.74	0.74	0.74			10.23
ES-C-075-80-1				0.74	0.74	0.74	80		10.47
ES-C-075-80-2				0.74	0.74	0.74			10.33
ES-C-075-80-3				0.74	0.74	0.74			10.51
ES-C-100-40-1			1.00	1.06	1.07	1.07	40	0.14	21.45
ES-C-100-40-2				1.07	1.07	1.07			21.35
ES-C-100-40-3				1.07	1.07	1.07			20.63
ES-C-100-80-1				1.07	1.07	1.07	80		20.63
ES-C-100-80-2				1.07	1.07	1.07			20.98
ES-C-100-80-3				1.07	1.07	1.07			20.53
ES-Z-075-40-1	410	540	0.75	0.74	0.75	0.75	40	0.14	9.72
ES-Z-075-40-2				0.75	0.74	0.76			9.78
ES-Z-075-40-3				0.75	0.76	0.75			10.44
ES-Z-075-80-1				0.74	0.74	0.74	80		9.67
ES-Z-075-80-2				0.75	0.75	0.74			9.82
ES-Z-075-80-3				0.75	0.75	0.75			9.63
ES-Z-100-40-1			1.00	0.98	0.98	0.98	40	0.14	16.54
ES-Z-100-40-2				0.98	0.98	0.98			16.47
ES-Z-100-40-3				0.98	0.98	0.98			16.33
ES-Z-100-80-1				0.98	0.98	0.98	80		15.97
ES-Z-100-80-2				0.98	0.98	0.99			14.98
ES-Z-100-80-3				0.98	0.98	0.98			16.08

*) distance a = 136 mm, see annex F

Table 10: Results of end support tests

4.5 Measurement of the profile geometry

The dimensions of the different plank profiles (Cladeo, Zephir with and without end reinforcement) for both nominal thicknesses t_N = 0.75 mm and t_N = 1.00 mm were determined. The results are documented in annex G.

4.6 Material properties

For the determination of the material properties 1 specimen per test was worked out from the middle specimen of each test setup 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 annex H.

5 Summary

For the research project “Guidelines and Recommendations for Integrating Specific Profiled Steel 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 interlocking plank profiles. Also tensile tests according to EN 6892.1:2009 and profile geometry measurements were accomplished.

In chapter 2 the plank profiles 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.