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

Test report

Assembled 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 assembled profiles 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 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 trapezoidal sheets manufactured by Joris Ide consist of steel sheeting according to EN 10346:2009, which are formed to profiles 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]	Nominal thickness [mm]
JI D_137-310-930	S320GD	137	310	0.75 and 1.00
JI D_158-250-750	S320GD	158	250	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 in figure A.1 and figure A.2.

3 Scope of testing

The test performances for determination of the resistance values for bending and web crippling for continuous profiles, overlap joints according to 18807, overlap joints and continuous profiles with local reinforcement were done according to EN 1993-1-3:2010. The tests performed are listed in table 2 as follows. The description of the different assemblies is given in annex A, figure A.3. The fixation was executed with screws from SFS (SL2-4,8x20). 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]	Type	Support width [mm]	Span [mm]		Number of tests	
				JI D_137	JI D_158	JI D_137	JI D_158
Internal support tests with gravity loading	0.75	Continuous profile (C)	60	800	800	2	2
				2400	2800	2	2
			160	800	800	2	2
				2400	2800	2	2
	1.00		60	800	800	2	2
				2800	3200	2	2
			160	800	800	2	3
				2800	3200	2	2
	0.75	Joint according to DIN 18807 (DIN)	60	800	800	2	2
				2400	2800	2	2
			160	800	800	2	2
				2400	2800	2	2
	1.00		60	800	800	2	2
				2800	3200	2	2
			160	800	800	2	2
				2800	3200	2	2
	0.75	Overlap (OL)	60	800	800	2	2
				1300	800	1	2
				2400	2800	2	2
			160	800	800	2	2
				2400	2800	2	3
	1.00		60	800	800	2	2
				2800	3200	2	2
			160	800	800	2	2
				2800	3200	2	2
	0.75	Continuous profile with local rein-forcement (CR)	60	800	800	2	2
				2400	2800	2	2
			160	800	800	2	2
				2400	2800	2	2
	1.00		60	800	800	2	2
				2800	3200	2	2
			160	800	800	2	2
				2800	3200	2	2

Table 2: Tests performed with JI D_137-310-930 and JI D_158-250-750

4 Test performance and results

4.1 General remarks

The test specimens were delivered May 11th and July 08th 2015. The tests were performed using calibrated testing machines of Versuchsanstalt für Stahl, Holz und Steine (KIT). The specimens are all described by the following system:

Internal support test (IS):

System:	IS – XXX – XXX – XXX – XXX – XXX – X	
First block:	Profile height [mm]	
(three char.)	135	= JI D_137-310-930
	158	= JI D_158-250-750
Second block:	type of assembly	
(one to three char.)	C	= continuous profile without assembly
	DIN	= joint according to DIN 18807
	OL	= overlap joint
	CR	= continuous profile with local reinforcement
Third block:	Support width [mm]	
(two or three char.)	60	= 60 mm
	160	= 160 mm
Fourth block:	Sheet thickness	
(two or three char.):	75	= 0.75 mm
	100	= 1.00 mm
Fifth block:	Span length [cm]	
(two or three char.)		
Sixth block (one char.):	Test Number (running)	

4.2 Internal support tests

Instead of extensive investigations of the intermediate support area of continuous beams, internal support tests for load case “gravity loading” were performed. The tests performed are shown in table 2. Loading was applied in mid-span via a transverse steel plate with a width of b_u = 60 mm or b_u = 160 mm. Transverse ties prevented the profiles from spreading. At the supports the profiles were pivoted on timber blocks. 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 plate. The structure of the specimens and the static system are given in annex B.

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 through a combination of deformations of the web (web-crippling) and buckling of the compressed flanges of the profile. In the tests with short span, the local compression of the profile and web-crippling dominated the failure mode, in the tests with long span buckling of the upper flange became more important.

The results of the internal support tests are listed in the following five tables. The lengths L3, L1 and L2 are described in annex B. The overlap between the screws was a = 500 mm (JI D_137-310-930) or a = 600 mm (JI D_158-250-750).The load F_{max} indicates the failure load including preload, but without self-weight of the specimen. In table 3 the results of internal support tests for continuous profiles are shown. Table 4 shows the results for joints according to DIN 18807. The results for overlapped joints are given in table 5 and table 6. In table 7 the results for continuous profiles with local reinforcement are shown.

The measured nominal thickness including zinc coating which is documented in the following five tables was always measured at the continuous profile (for type C and CR) or at the left side of the assembly, see annex B (type DIN and OL). Annex B shows the test setup, photos of the tests and the load deflection-curves for load case “gravity loading”.

Test	Span [mm]	Length L3 [mm]	Width of support [mm]	Nominal thickness [mm]	Measured t_N incl. zinc coating [mm]	Preload [kN]	F_{max} [kN]
IS-135-C-60-75-80-1	800	1500	60	0.75	0.73	0.12	10.59
IS-135-C-60-75-80-2					0.73		10.48
IS-135-C-60-75-240-1	2400	2800			0.74	0.20	6.69
IS-135-C-60-75-240-2					0.73		6.95
IS-135-C-160-75-80-1	800	1500	160		0.72	0.12	12.91
IS-135-C-160-75-80-2					0.73		13.15
IS-135-C-160-75-240-1	2400	2800			0.73	0.20	8.34
IS-135-C-160-75-240-2					0.73		8.62
IS-135-C-60-100-80-1	800	1500	60	1.00	0.98	0.18	18.09
IS-135-C-60-100-80-2					0.98		17.96
IS-135-C-60-100-280-1	2800	3200			0.98	0.20	9.53
IS-135-C-60-100-280-2					0.99		9.36
IS-135-C-160-100-80-1	800	1500	160		0.98	0.18	22.49
IS-135-C-160-100-80-2					0.98		22.33
IS-135-C-160-100-280-1	2800	3200			0.98	0.20	11.55
IS-135-C-160-100-280-2					0.99		11.96
IS-158-C-60-75-80-1	800	1500	60	0.75	0.73	0.18	10.74
IS-158-C-60-75-80-2					0.79		10.85
IS-158-C-60-75-280-1	2800	3200			0.79	0.20	7.35
IS-158-C-60-75-280-2					0.72		7.16
IS-158-C-160-75-80-1	800	1500	160		0.74	0.18	17.67
IS-158-C-160-75-80-2					0.72		17.50
IS-158-C-160-75-280-1	2800	3200			0.73	0.20	9.08
IS-158-C-160-75-280-2					0.73		9.16
IS-158-C-60-100-80-1	800	1500	60	1.00	0.99	0.18	19.79
IS-158-C-60-100-80-2					0.99		19.91
IS-158-C-60-100-320-1	3200	3600			0.99	0.20	11.87
IS-158-C-60-100-320-2					0.99		11.84
IS-158-C-160-100-80-1	800	1500	160		0.98	0.18	29.99
IS-158-C-160-100-80-2					0.98		32.31
IS-158-C-160-100-80-3					0.98		32.10
IS-158-C-160-100-320-1	3200	3600			0.99	0.20	13.83
IS-158-C-160-100-320-2					0.99		14.20

Table 3: Results of internal support tests for load case “gravity loading” for type C

Test	Span [mm]	Length L3, L1, L2 [mm]	Width of support [mm]	Nominal thickness [mm]	Measured t_N incl. zinc coating [mm]	Preload [kN]	F_{max} [kN]
IS-135-DIN-60-75-80-1	800	1500 1300 800	60	0.75	0.73	0.12	16.89
IS-135-DIN-60-75-80-2					0.73		16.47
IS-135-DIN-60-75-240-1	2400	2800 1950 1450			0.72	0.20	5.94
IS-135-DIN-60-75-240-2					0.74		5.94
IS-135-DIN-160-75-80-1	800	1500 1300 800	160		0.73	0.12	17.16
IS-135-DIN-160-75-80-2					0.73		17.57
IS-135-DIN-160-75-240-1	2400	2800 1950 1450			0.73	0.20	6.77
IS-135-DIN-160-75-240-2					0.73		6.14
IS-135-DIN-60-100-80-1	800	1500 1300 800	60	1.00	0.98	0.18	27.69
IS-135-DIN-60-100-80-2					0.99		27.10
IS-135-DIN-60-100-280-1	2800	3200 2150 1650			0.98	0.20	11.33
IS-135-DIN-60-100-280-2					0.98		11.20
IS-135-DIN-160-100-80-1	800	1500 1300 800	160		0.98	0.18	30.09
IS-135-DIN-160-100-80-2					0.98		30.02
IS-135-DIN-160-100-280-1	2800	3200 2150 1650			0.99	0.20	12.49
IS-135-DIN-160-100-280-2					0.99		12.12
IS-158-DIN-60-75-80-1	800	1500 1400 800	60	0.75	0.73	0.18	19.24
IS-158-DIN-60-75-80-2					0.72		19.15
IS-158-DIN-60-75-280-1	2800	3200 2250 1650			0.73	0.20	8.45
IS-158-DIN-60-75-280-2					0.73		8.38
IS-158-DIN-160-75-80-1	800	1500 1400 800	160		0.72	0.18	24.27
IS-158-DIN-160-75-80-2					0.73		24.08
IS-158-DIN-160-75-280-1	2800	3200 2250 1650			0.73	0.20	7.91
IS-158-DIN-160-75-280-2					0.73		8.27
IS-158-DIN-60-100-80-1	800	1500 1400 800	60	1.00	0.98	0.18	34.73
IS-158-DIN-60-100-80-2					0.98		34.95
IS-158-DIN-60-100-320-1	3200	3600 2450 1850			0.99	0.20	13.58
IS-158-DIN-60-100-320-2					0.99		13.98
IS-158-DIN-160-100-80-1	800	1500 1400 800	160		0.98	0.18	41.55
IS-158-DIN-160-100-80-2					0.99		39.90
IS-158-DIN-160-100-320-1	3200	3600 2450 1850			0.99	0.20	14.21
IS-158-DIN-160-100-320-2					1.00		14.22

Table 4: Results of internal support tests for load case “gravity loading” for type DIN

Test	Span [mm]	Length L3, L1, L2 [mm]	Width of support [mm]	Nominal thickness [mm]	Measured t_N incl. zinc coating [mm]	Preload [kN]	F_{max} [kN]
IS-135-OL-60-75-80-1	800	1500 1300 1300	60	0.75	0.72	0.12	20.84
IS-135-OL-60-75-80-2					0.74		20.65
IS-135-OL-60-75-130-1	1300	1500 1300 1300			0.73	0.18	17.87
IS-135-OL-60-75-240-1	2400	2800 1950 1950			0.73	0.20	12.64
IS-135-OL-60-75-240-2					0.72		12.81
IS-135-OL-160-75-80-1	800	1500 1300 1300	160		0.72	0.12	25.81
IS-135-OL-160-75-80-2					0.73		26.23
IS-135-OL-160-75-240-1	2400	2800 1950 1950			0.73	0.20	13.80
IS-135-OL-160-75-240-2					0.74		13.60
IS-135-OL-60-100-80-1	800	1500 1300 1300	60	1.00	0.99	0.18	35.38
IS-135-OL-60-100-80-2					0.98		37.39
IS-135-OL-60-100-80-3					0.97		34.66
IS-135-OL-60-100-280-1	2800	3200 2150 2150			0.99	0.20	18.87
IS-135-OL-60-100-280-2					0.98		18.84
IS-135-OL-160-100-80-1	800	1500 1300 1300	160		0.98	0.18	43.95
IS-135-OL-160-100-80-2					0.98		43.75
IS-135-OL-160-100-280-1	2800	3200 2150 2150			0.99	0.20	19.35
IS-135-OL-160-100-280-2					0.98		19.51

Table 5: Results of internal support tests for load case “gravity loading” for type OL

Test	Span [mm]	Length L3, L1, L2 [mm]	Width of support [mm]	Nominal thickness [mm]	Measured t_N incl. zinc coating [mm]	Preload [kN]	F_{max} [kN]
IS-158-OL-60-75-80-1	800	1500 1400 1400	60	0.75	0.73	0.18	22.58
IS-158-OL-60-75-80-2					0.73		22.63
IS-158-OL-60-75-80-V1*)	800				0.73	0.18	21.70
IS-158-OL-60-75-80-V2*)					0.74		21.60
IS-158-OL-60-75-280-1	2800	3200 2250 2250			0.73	0.20	14.19
IS-158-OL-60-75-280-2					0.73		14.19
IS-158-OL-160-75-80-1	800	1500 1400 1400	160		0.73	0.18	34.40
IS-158-OL-160-75-80-2					0.74		34.85
IS-158-OL-160-75-280-1	2800	3200 2250 2250			0.73	0.20	14.02
IS-158-OL-160-75-280-2					0.73		15.53
IS-158-OL-160-75-280-3					0.73		15.37
IS-158-OL-60-100-80-1	800	1500 1400 1400	60	1.00	0.99	0.18	41.55
IS-158-OL-60-100-80-2					0.99		41.27
IS-158-OL-60-100-320-1	3200	3600 2450 2450			1.00	0.20	22.28
IS-158-OL-60-100-320-2					0.99		22.38
IS-158-OL-160-100-80-1	800	1500 1400 1400	160		0.99	0.18	60.62
IS-158-OL-160-100-80-2					0.99		59.11
IS-158-OL-160-100-320-1	3200	3600 2450 2450			1.00	0.20	23.33
IS-158-OL-160-100-320-2					1.00		23.15

*) without central fixation

Table 6: Results of internal support tests for load case “gravity loading” for type OL

Test	Span [mm]	Length L3, L1, L2 [mm]	Width of support [mm]	Nominal thickness [mm]	Measured t_N incl. zinc coating [mm]	Preload [kN]	F_{max} [kN]
IS-135-CR-60-75-80-1	800	1500 - 1100	60	0.75	0.73	0.12	20.96
IS-135-CR-60-75-80-2					0.73		20.89
IS-135-CR-60-75-240-1	2400	2800 - 1100			0.73	0.20	12.60
IS-135-CR-60-75-240-2					0.74		12.69
IS-135-CR-160-75-80-1	800	1500 - 1100	160		0.73	0.12	26.05
IS-135-CR-160-75-80-2					0.73		26.12
IS-135-CR-160-75-240-1	2400	2800 - 1100			0.73	0.20	13.62
IS-135-CR-160-75-240-2					0.74		13.58
IS-135-CR-60-100-80-1	800	1500 - 1100	60	1.00	0.98	0.18	37.25
IS-135-CR-60-100-80-2					0.98		37.29
IS-135-CR-60-100-280-1	2800	3200 - 1100			0.99	0.20	18.44
IS-135-CR-60-100-280-2					0.99		18.68
IS-135-CR-160-100-80-1	800	1500 - 1100	160		0.98	0.18	43.88
IS-135-CR-160-100-80-2					0.98		43.74
IS-135-CR-160-100-280-1	2800	3200 - 1100			0.99	0.20	19.47
IS-135-CR-160-100-280-2					0.99		20.17
IS-158-CR-60-75-80-1	800	1500 - 1300	60	0.75	0.73	0.18	22.52
IS-158-CR-60-75-80-2					0.72		22.45
IS-158-CR-60-75-280-1	2800	3200 - 1300			0.73	0.20	13.80
IS-158-CR-60-75-280-2					0.73		13.98
IS-158-CR-160-75-80-1	800	1500 - 1300	160		0.72	0.18	33.81
IS-158-CR-160-75-80-2					0.73		34.32
IS-158-CR-160-75-280-1	2800	3200 - 1300			0.73	0.20	15.67
IS-158-CR-160-75-280-2					0.73		15.43
IS-158-CR-60-100-80-1	800	1500 - 1300	60	1.00	0.98	0.18	41.16
IS-158-CR-60-100-80-2					0.98		41.14
IS-158-CR-60-100-320-1	3200	3600 - 1300			0.99	0.20	21.62
IS-158-CR-60-100-320-2					0.99		21.61
IS-158-CR-160-100-80-1	800	1500 - 1300	160		0.99	0.18	60.01
IS-158-CR-160-100-80-3					0.99		57.07
IS-158-CR-160-100-320-1	3200	3600 - 1300			0.99	0.20	22.13
IS-158-CR-160-100-320-2					0.99		22.25

Table 7: Results of internal support tests for load case “gravity loading” for type CR

4.3 Measurement of the profile geometry

The dimensions of the different profiles (JI D_137-310-930 and JI D_158-250-750) for both nominal thicknesses t_N = 0.75 mm and t_N = 1.00 mm were determined. The results are documented in annex C.

4.4 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 8.

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_137-310-930	0.75	0.702	349	406	27.0
		0.707	348	406	27.0
		0.704	349	406	26.7
	1.00	0.954	328	394	28.4
		0.956	327	391	27.6
		0.958	327	392	27.4
JI D_158-250-750	0.75	0.702	344	412	26.6
		0.703	347	410	27.1
		0.701	347	411	26.9
	1.00	0.963	355	383	29.6
		0.962	356	382	30.3
		0.962	355	384	30.6

Table 8: 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 assembled profiles. Also tensile tests according to EN 6892.1:2009 and profile geometry measurements were accomplished.

In chapter 2 the assembled 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.