Ensuring Advancement in Sandwich Construction Through Innovation and Exploitation

TEST REPORT

No.: D3.2 – part 3

Tests on axially loaded sandwich panels

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Task: 3.4

Object: Global load bearing capacity of axially loaded sandwich panels

This report includes 45 pages.

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1 Preliminary remark

Traditionally sandwich panels are used as covering elements of buildings. In this application the panels only transfer transverse loads (wind, snow) to the substructure by bending. In the panels only the stress resultants of bending moment and transverse force are effective. A recent tendency, especially in the area of smaller buildings – such as cooling chambers, climatic chambers and clean rooms – is to apply the panels without substructure. In addition to the stress resultants arising from transverse loads, the wall panels also have to transfer normal forces. This result in the question for the load-bearing capacity of the panels subjected to axial loads or a combination of axial and transverse loads.

A design concept for axially loaded sandwich panels was developed within the framework of the EASIE project. In deliverable D3.2 – part 3, the results of the experimental tests on axial loaded sandwich panels are presented. The evaluation of the results can be found in deliverable D3.3. Deliverable D3.3 is also dealing with the numerical calculations and the derivation of a design concept.

2 Object of testing

Investigations on different types of sandwich panels were performed (Tab.1). The length of the panels varied between 2500 mm and 3500 mm. For all tests specimens with the width 400 mm have been used.

No.	Core material	Core thickness	Face material	Face thickness	Profiling of faces
F	PUR	60	steel	0,75	lightly profiled
K	EPS	60	steel	0,60	flat
L	EPS	60	GFRP	1,8	flat

Tab. 1: tested types of sandwich panels

The geometry of one panel with profiled faces (type F) was measured. The results are shown in the following figure.

Fig. 1: Geometry of panel type F

3 Test set-up

The test set-up for performing the tests on axial loaded sandwich panels is outlined in Fig. 2 und Fig. 3.

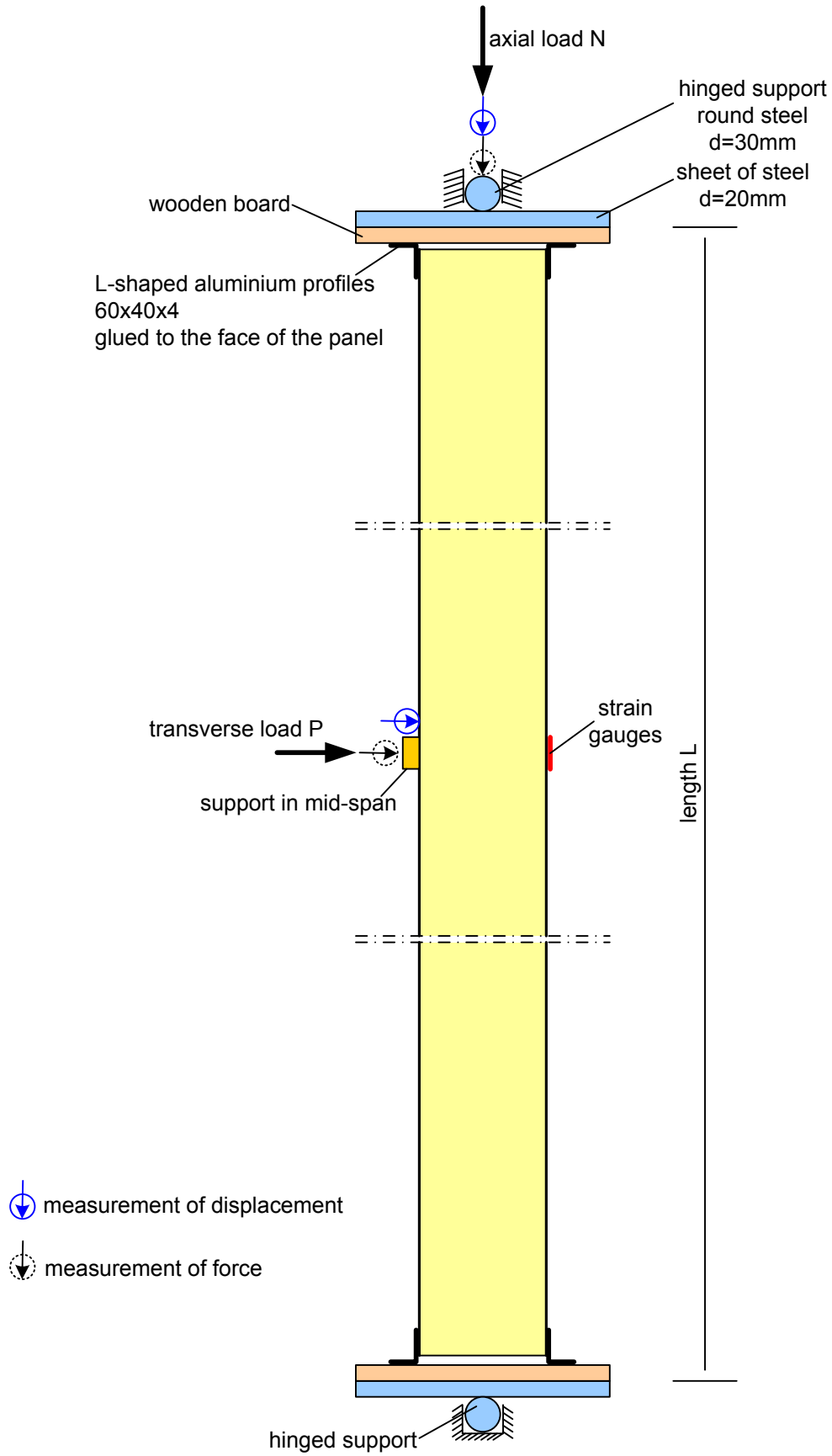


Fig. 2: Test set-up

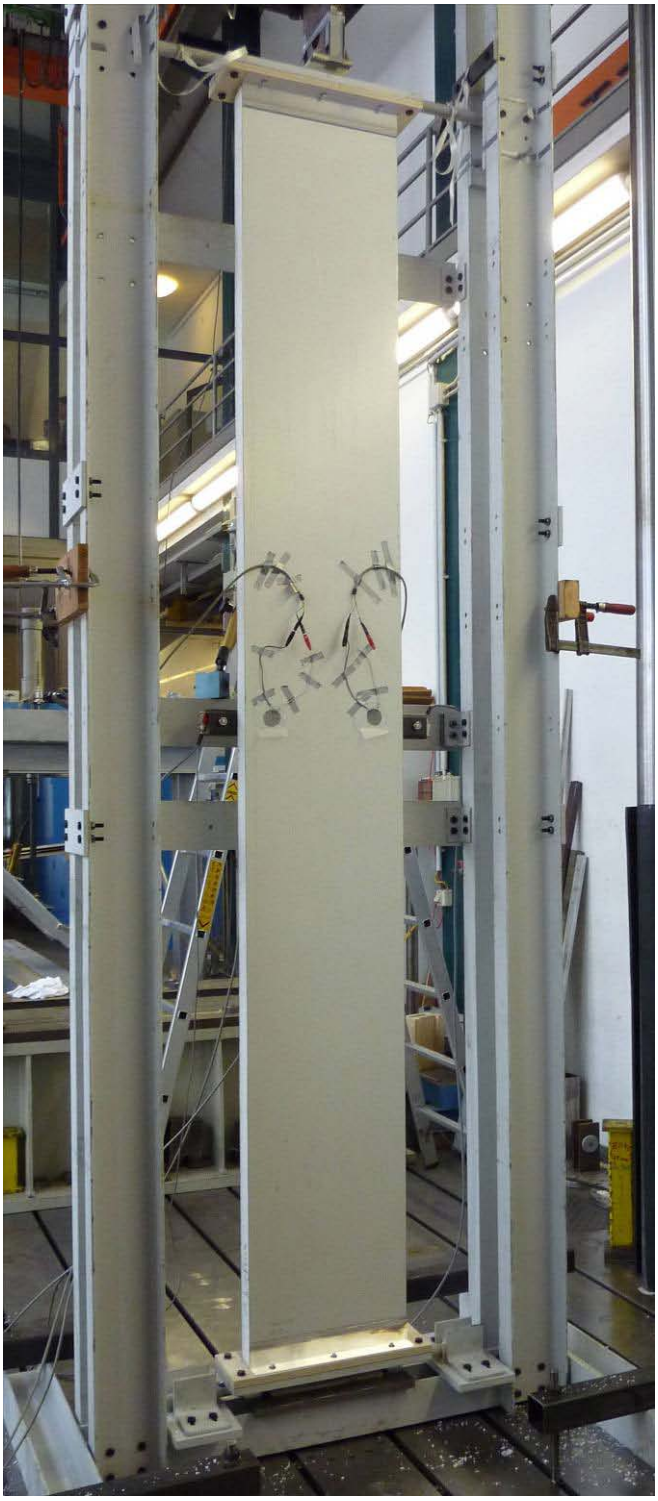


Fig. 3: Test set-up

For introducing the axial force L-shaped aluminium profiles 60x40x4 were glued on the faces of the panel. The profiles were screwed on a wooden board. The profiles were glued on the panels, thus there was a 5 mm gap between the wooden board and the end of the panel (Fig. 4).

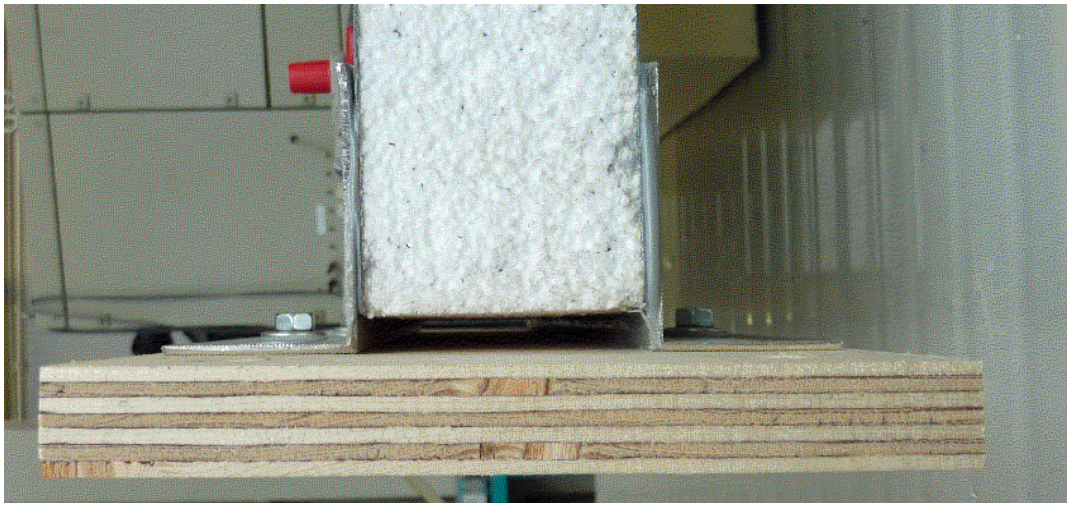


Fig. 4: Load introduction

The axial force N was introduced by a sheet of steel which was connected to a round steel. At the lower end of the panel the round steel was used as hinged support (Fig. 5). At the top end of the panel the round bar was supported hinged and vertical movable.

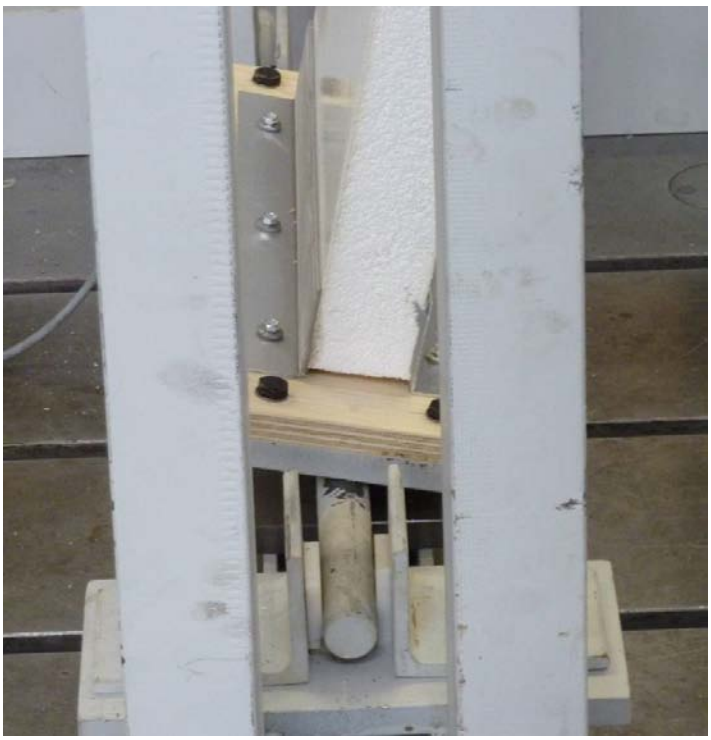


Fig. 5: Hinged support

In mid-span of the panel an additional support was located to apply an initial deflection to the panel. During the test the reaction force P and the deflection w was measured at mid-span (Fig. 6 and Fig. 7).
At the face subjected to tension two strain gauges were applied.

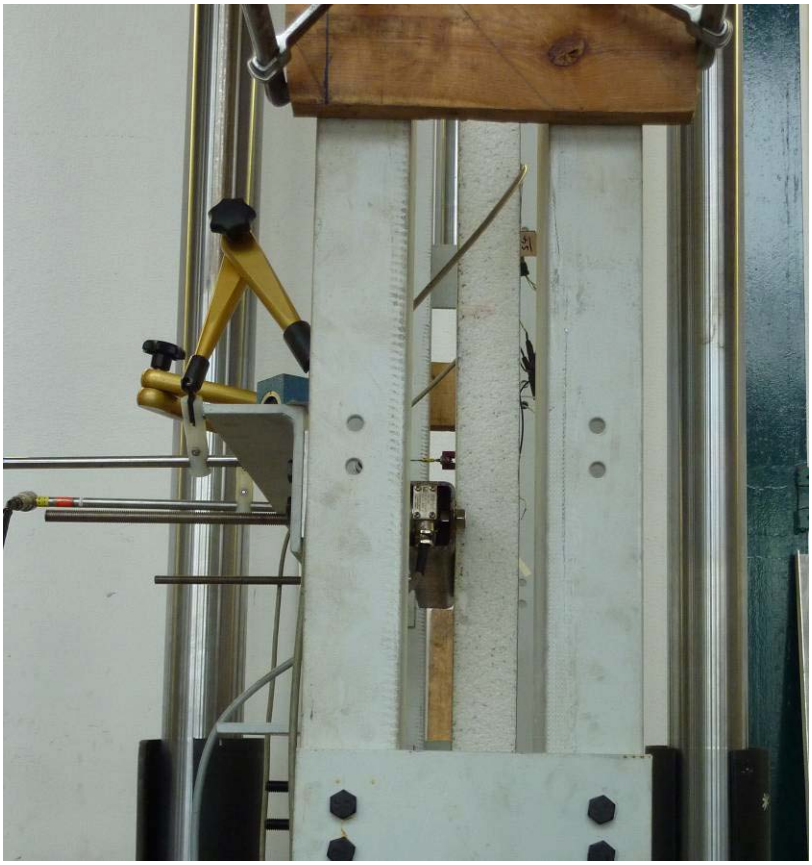


Fig. 6: Support at mid-span

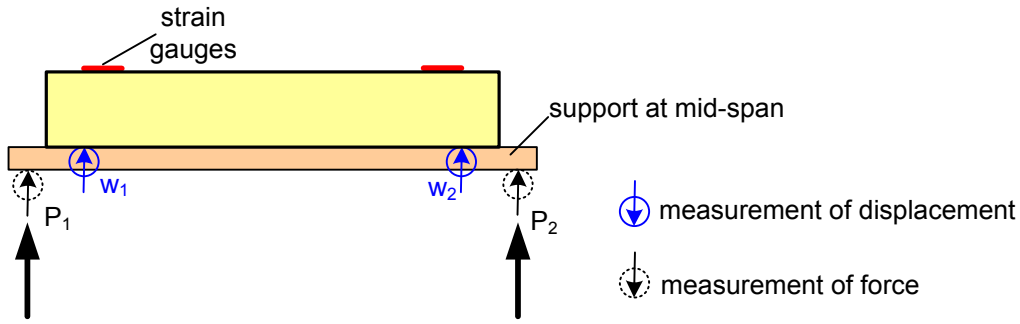


Fig. 7: Measurements at mid-span

4 Test performance

At the beginning of the test an initial deflection w_0 was applied to the panel at mid-span. At this position the support was fixed during the test. Following the axial force N was applied, the rate of loading was 1 mm/min.

During the test the axial force N, the reaction force P in mid-span and the deflection w of the panel was measured. Additionally the strain in the face subjected to tension was measured by the strain gauges.

5 Results of the tests

The following pages show the results of the tests on axial loaded sandwich panels. For each test, a table listing all relevant parameters is given, followed by the graphs of the measured values. In addition significant pictures are shown for each test.

No. 01

type of panel:	F
length of panel:	2500 mm
face material:	steel
face thickness:	0,75 / 0,75 mm
core material:	PU
core thickness:	60 mm

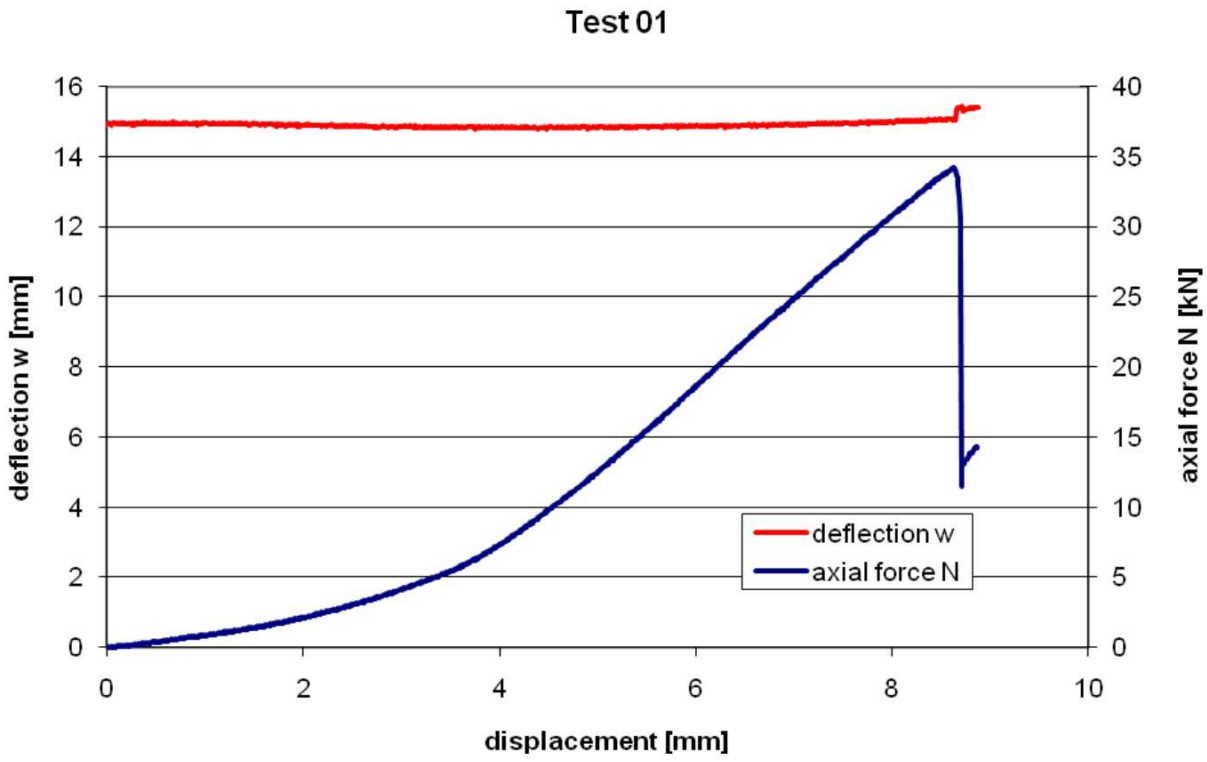
Measured dimensions

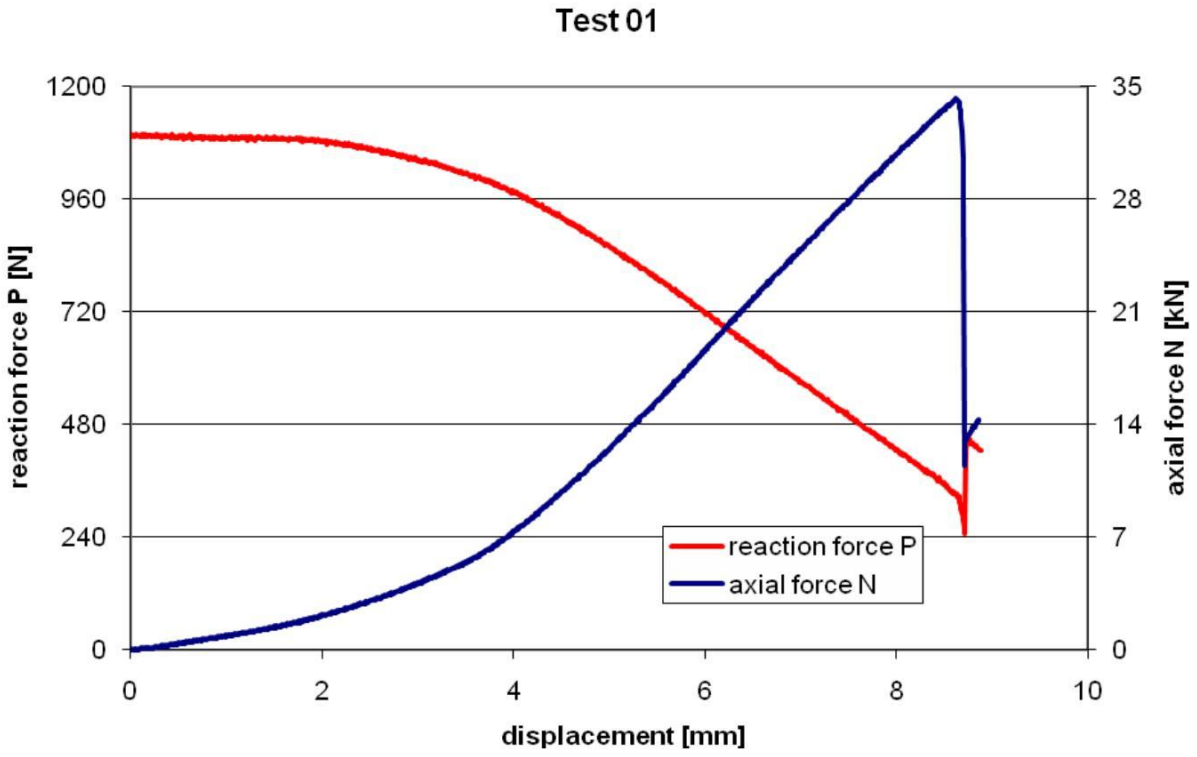
length L:	2548 mm
thickness of the panel B:	61,20 mm / 60,45 mm
width of the panel:	404 mm

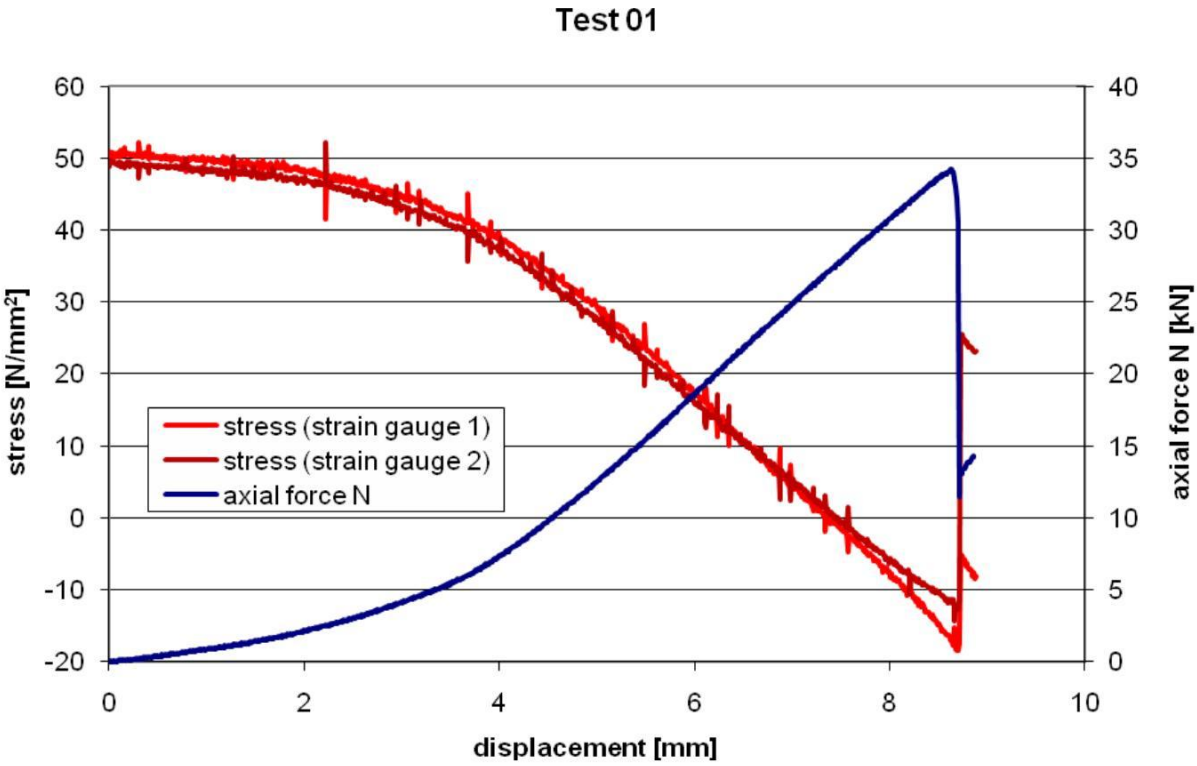
Initial deflection at mid-span w_0: 15,0 mm

max. axial load N:	34,4 kN
mode of failure:	Failure of glue at load introduction

remarks:







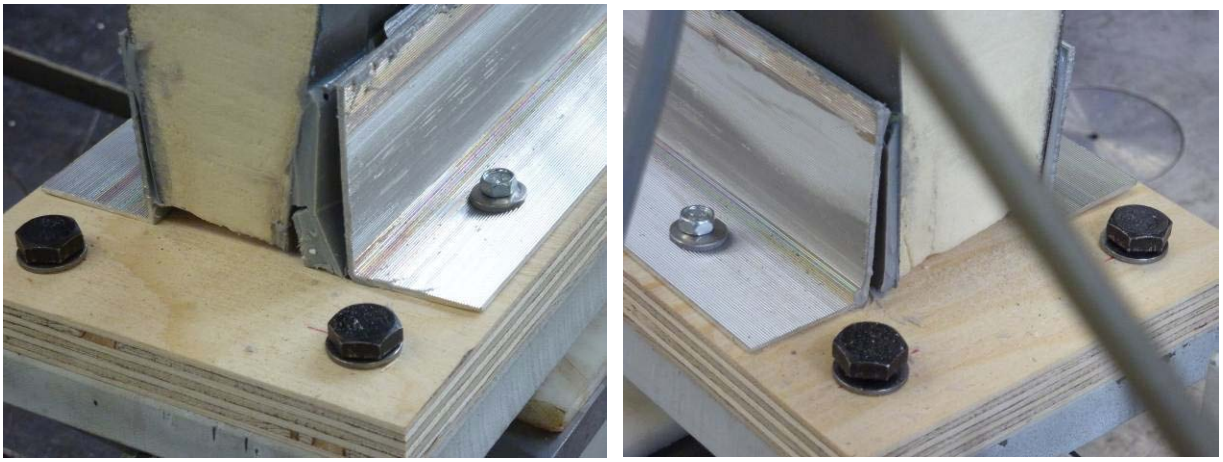


Fig. 8: Failure mode of test no. 01

No. 02

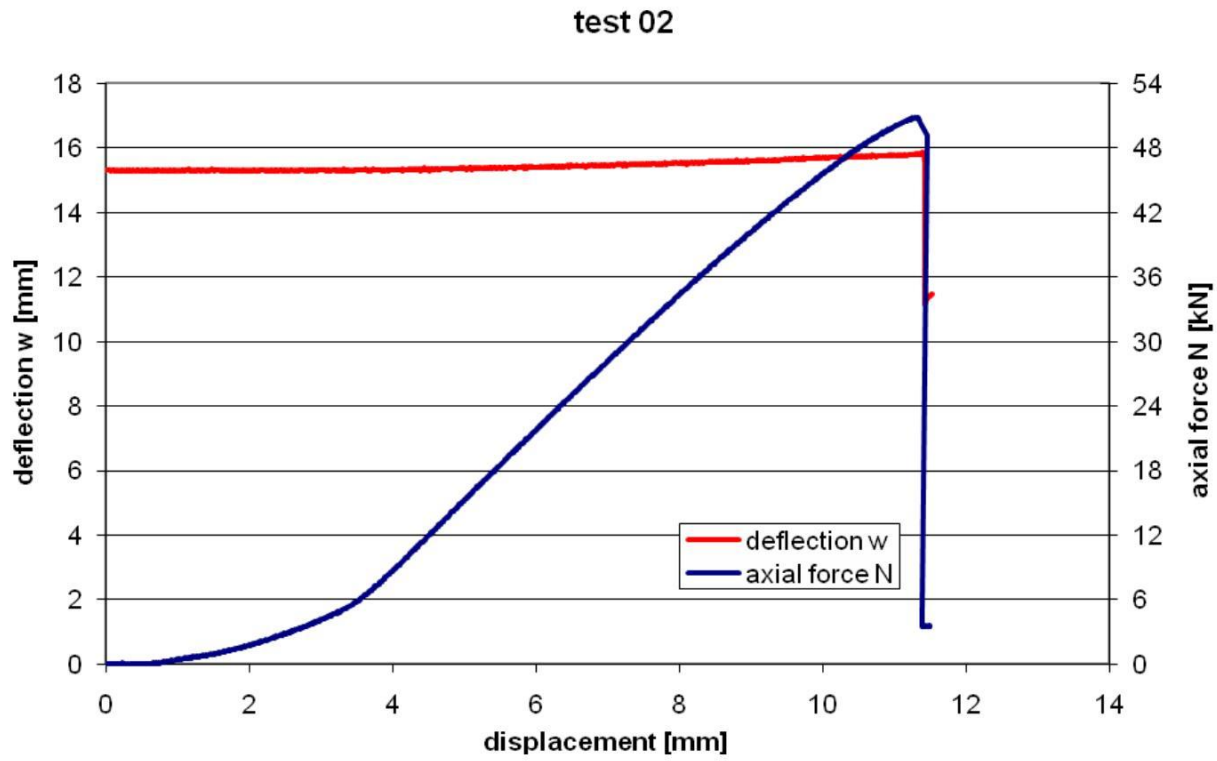
type of panel:	F
length of panel:	2500 mm
face material:	steel
face thickness:	0,75 / 0,75 mm
core material:	PU
core thickness:	60 mm

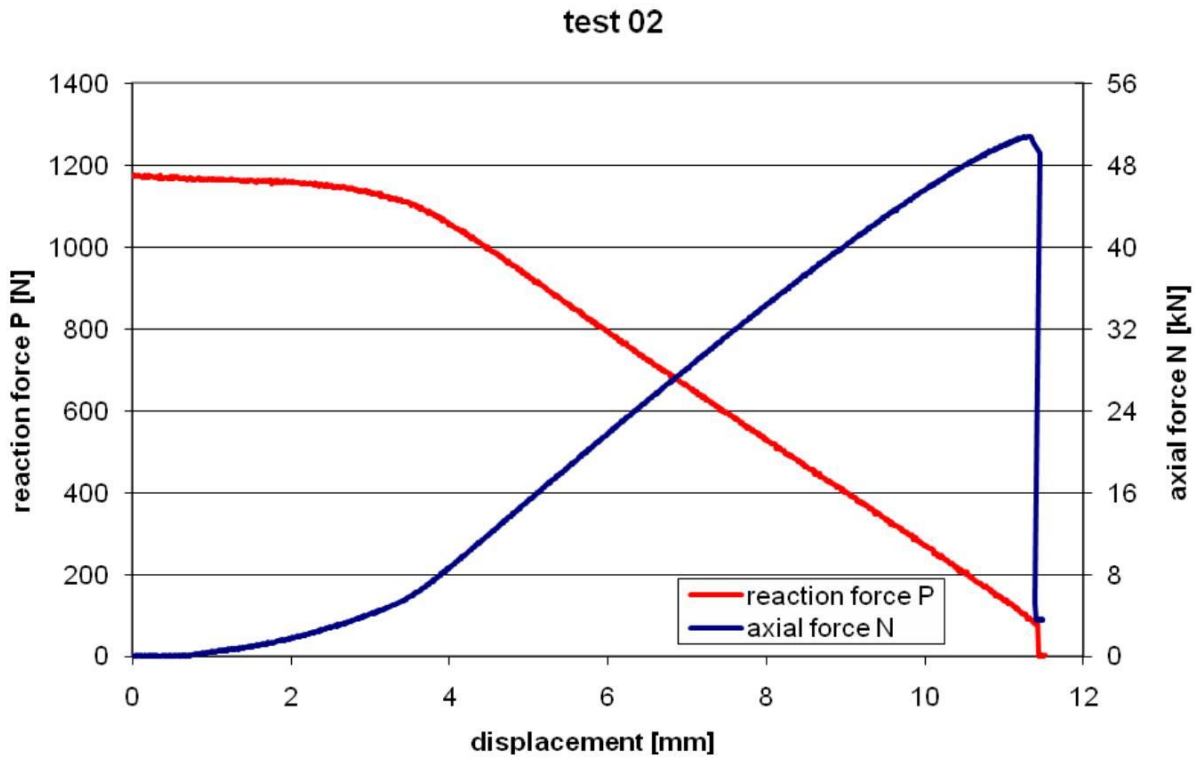
Measured dimensions

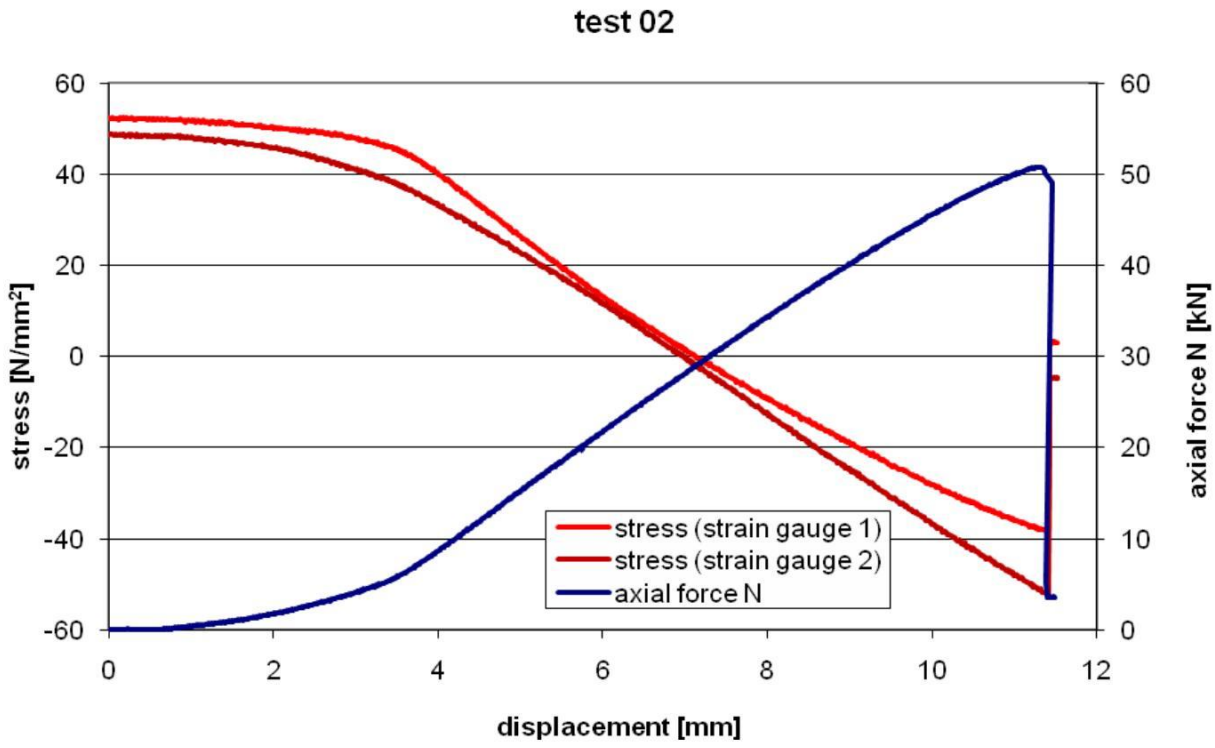
length L:	2545 mm
thickness of the panel:	60,52 mm / 60,82 mm
width of the panel:	402 mm

Initial deflection at mid-span w_0:	15 mm
max. axial load N:	51,0 kN
mode of failure:	Delamination of the face subjected to compression at the lower end

remarks:







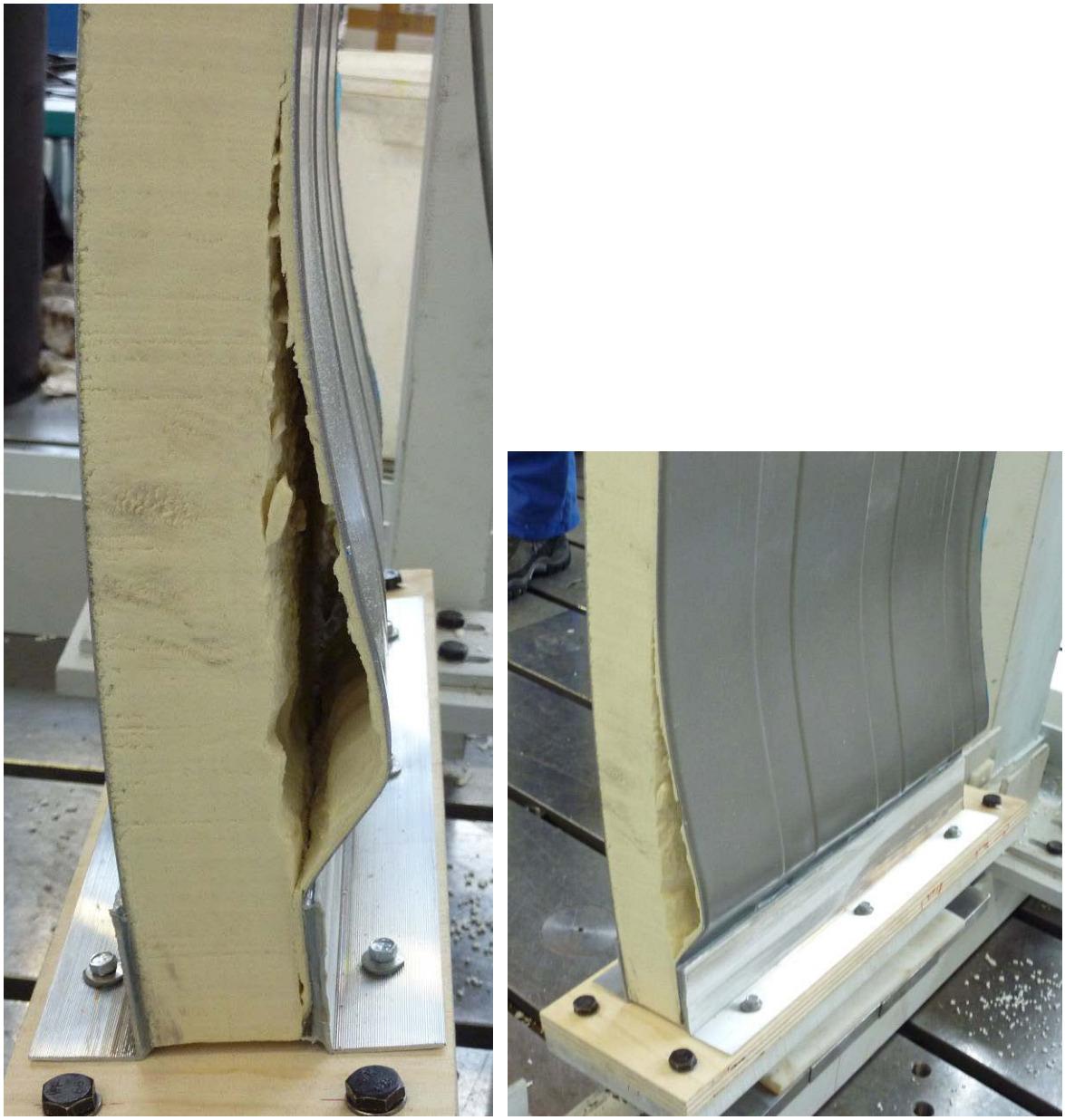


Fig. 9: Failure mode of test no. 02

No. 03

type of panel:	L
length of panel:	3000 mm
face material:	GFRP
face thickness:	1,8 / 1,8 mm
core material:	EPS
core thickness:	60 mm

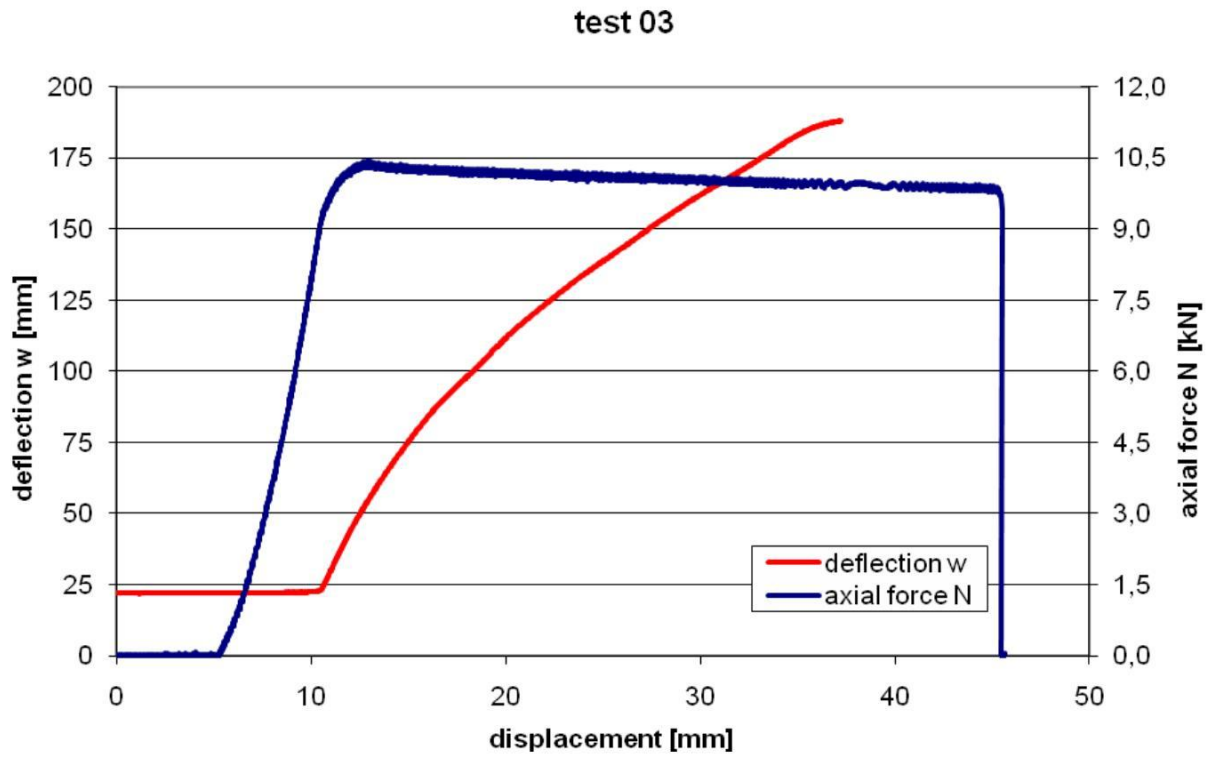
Measured dimensions

length L:	3043 mm
thickness of the panel:	61,59 mm / 62,06 mm
width of the panel:	399 mm

Initial deflection at mid-span w_0: 22 mm

max. axial load N:	10,6 kN
mode of failure:	Global buckling at max. N, shear failure of the core near load introduction after increasing the deflection

remarks:



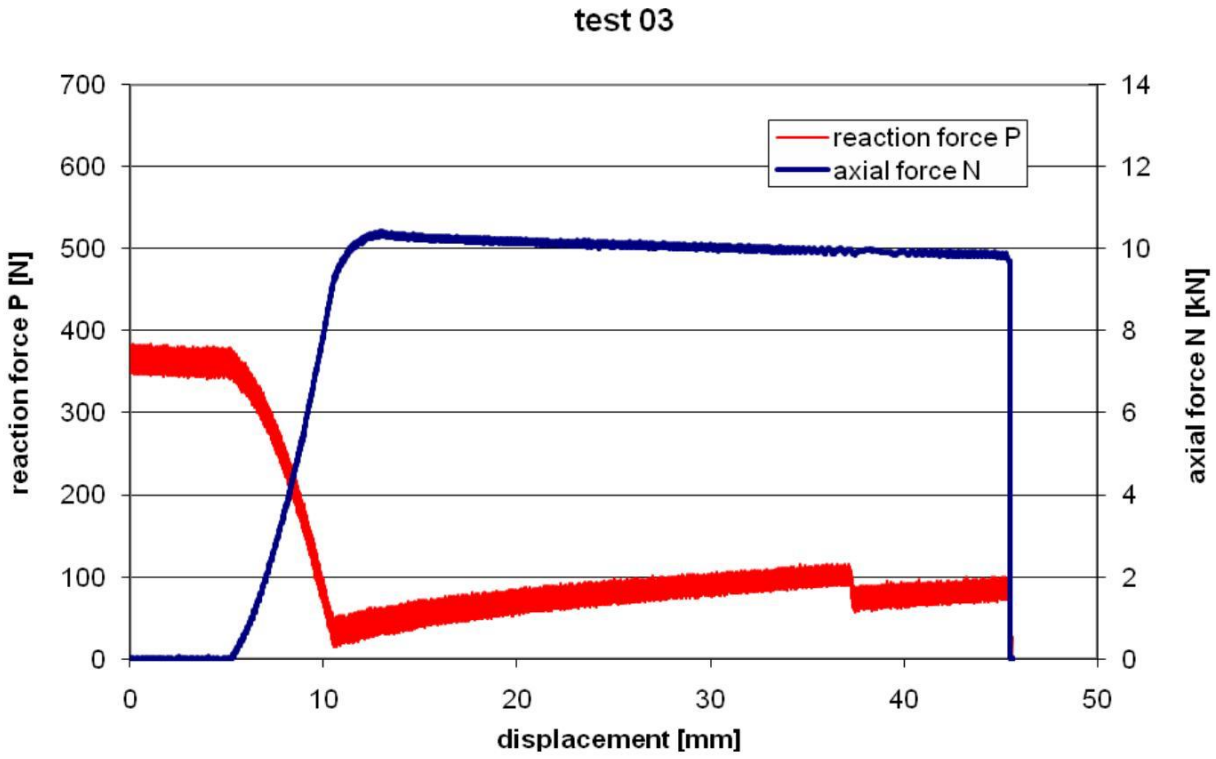


Fig. 10: specimen no. 03 during the test

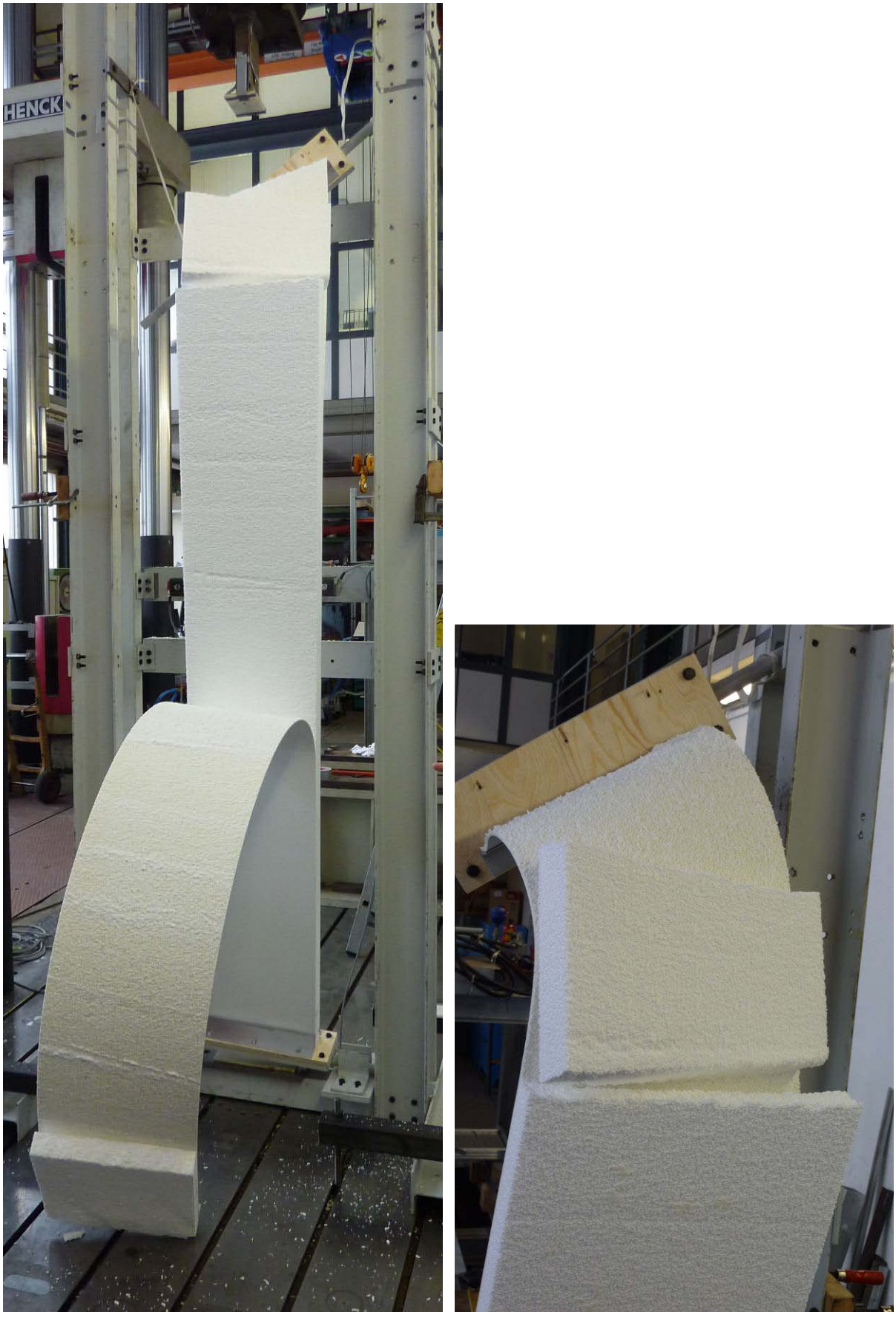


Fig. 11: Failure mode of test no. 03

No. 04

type of panel:	K
length of panel:	3000 mm
face material:	steel
face thickness:	0,60 / 0,60 mm
core material:	EPS
core thickness:	60 mm

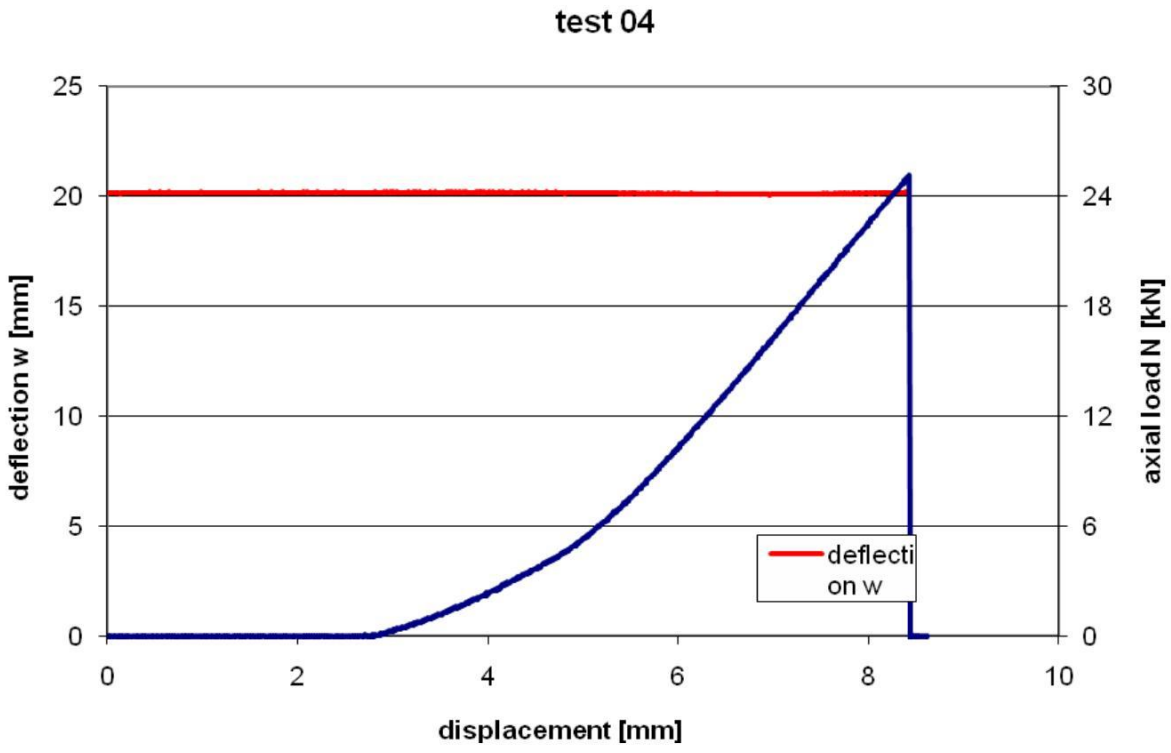
Measured dimensions

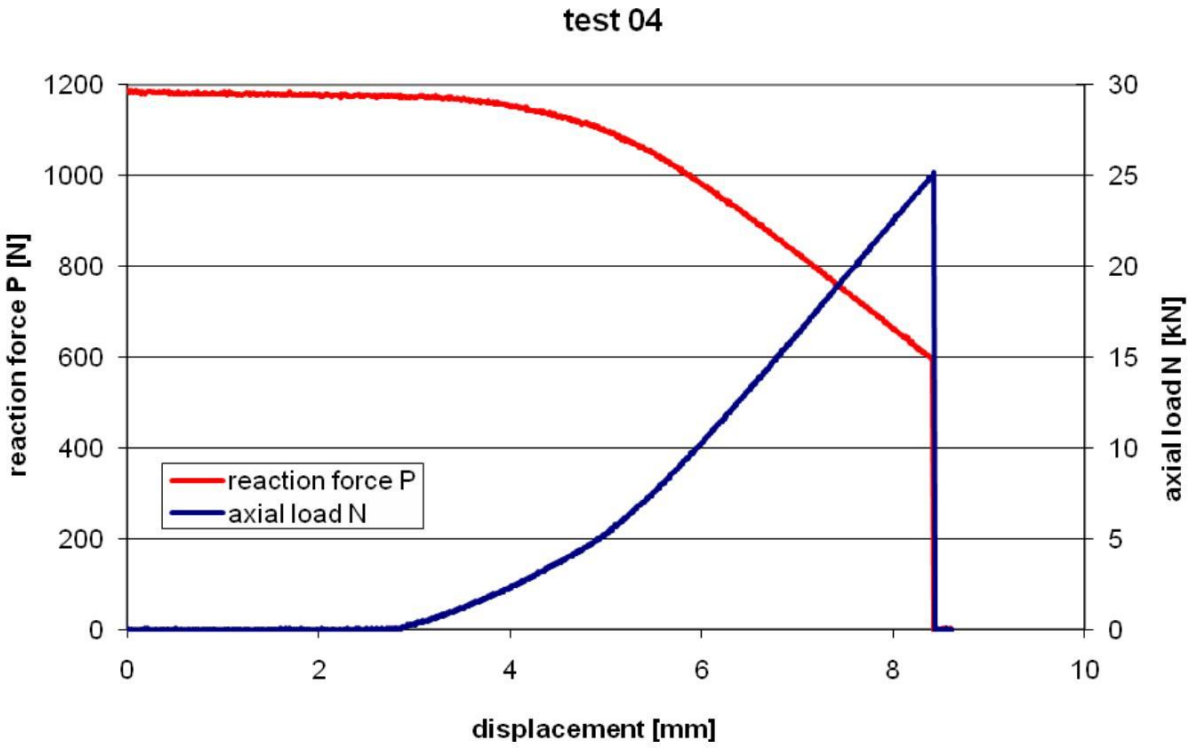
length L:	3049 mm
thickness of the panel:	59,94 mm / 59,62 mm
width of the panel:	399 mm

Initial deflection at mid-span w_0: 20 mm

max. axial load N:	25,3 kN
mode of failure:	Shear failure of the core near load introduction

remarks:





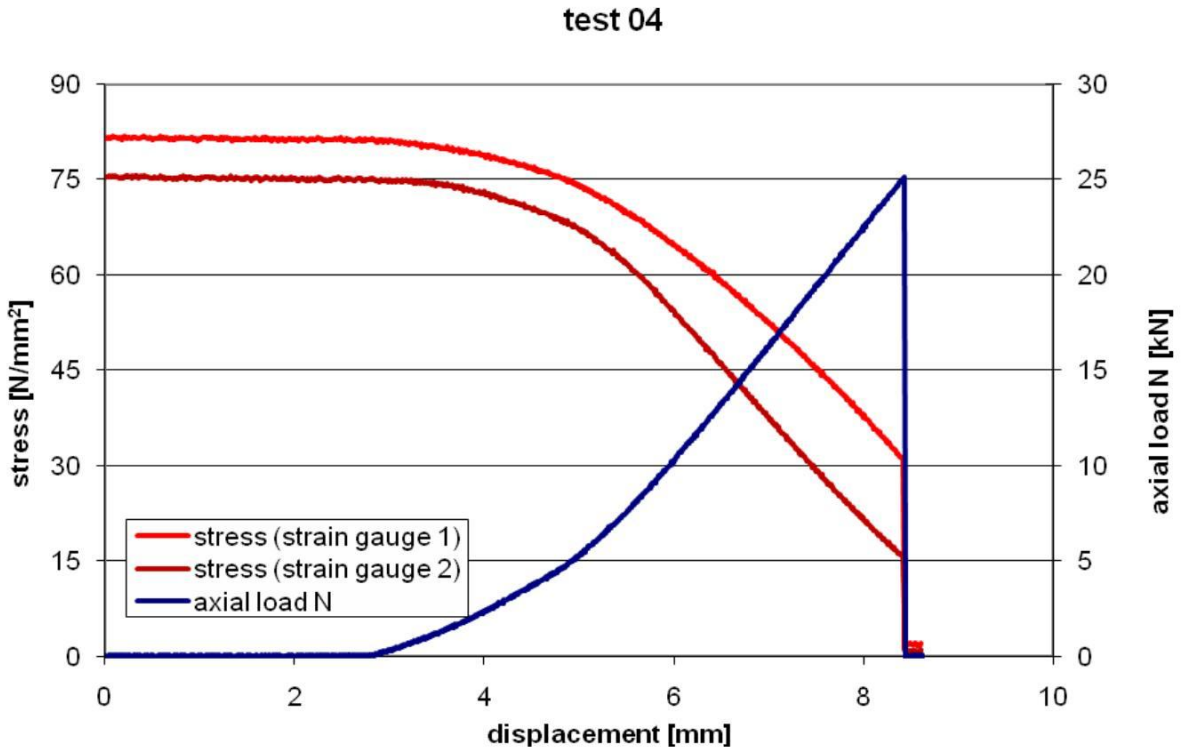


Fig. 12: Failure mode of test no. 04

No. 05

type of panel:	F
length of panel:	3000 mm
face material:	steel
face thickness:	0,75 / 0,75 mm
core material:	PU
core thickness:	60 mm

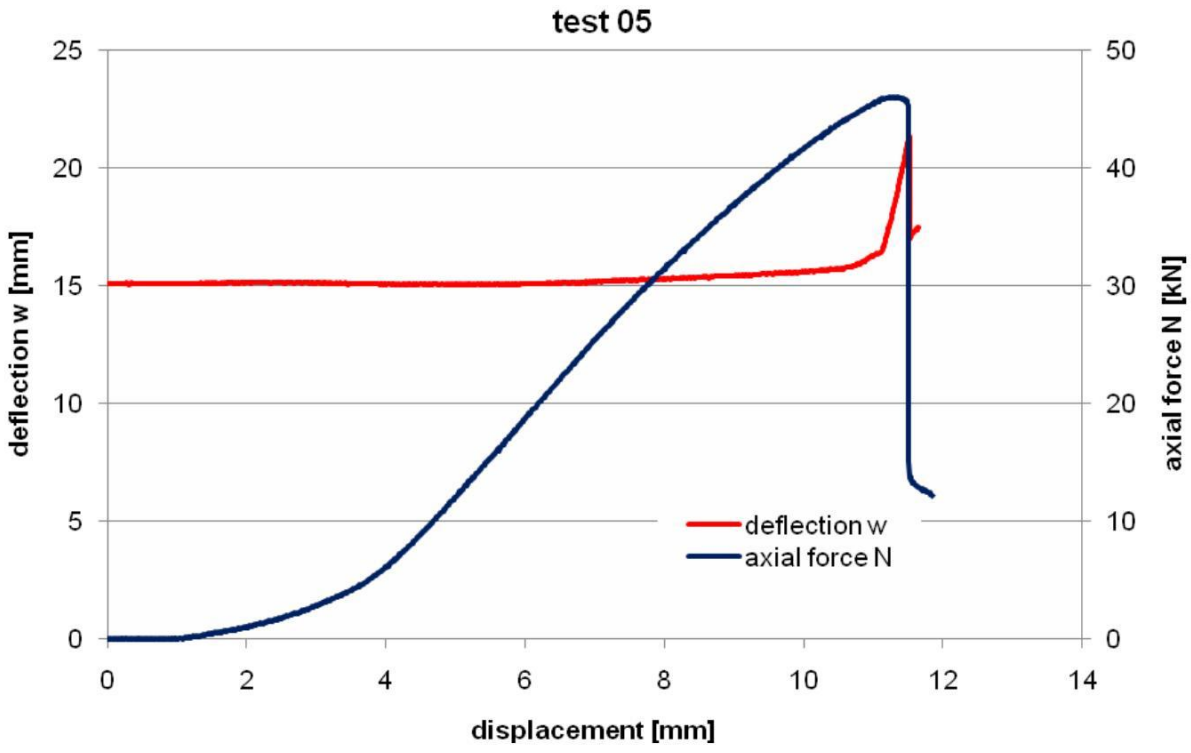
Measured dimensions

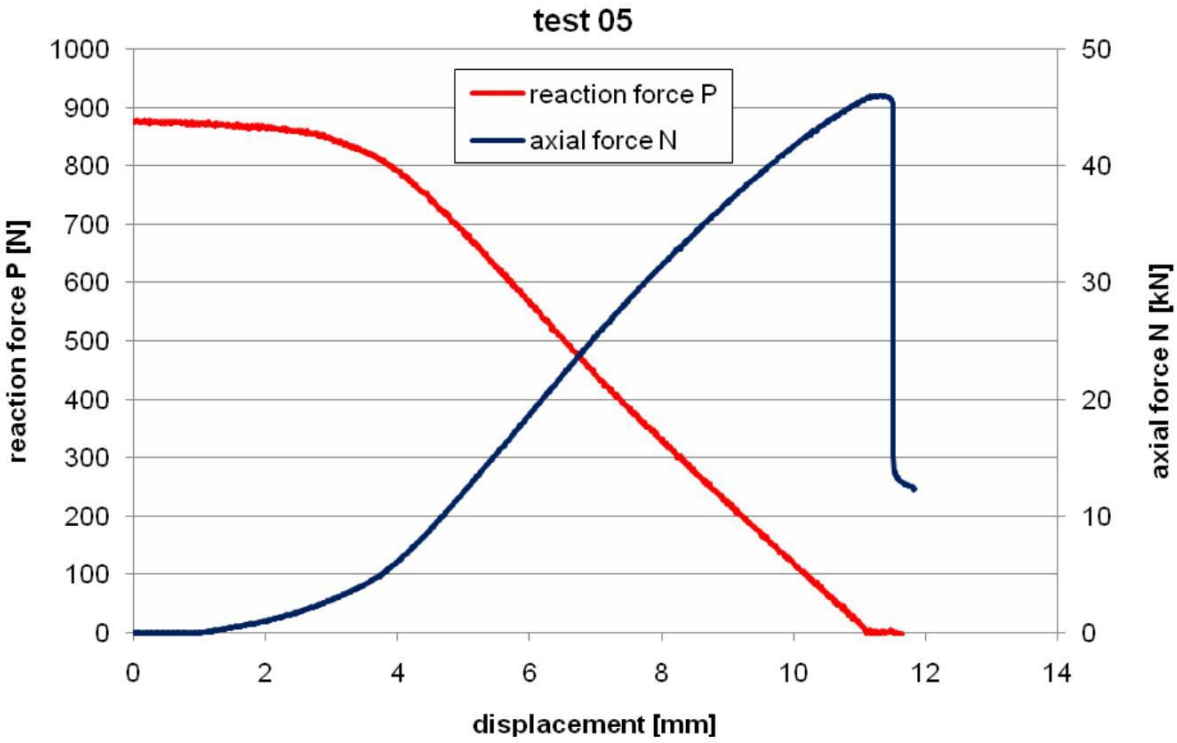
length L:	3049 mm
thickness of the panel B*:	59,38 mm / 59,92 mm
width of the panel:	401 mm

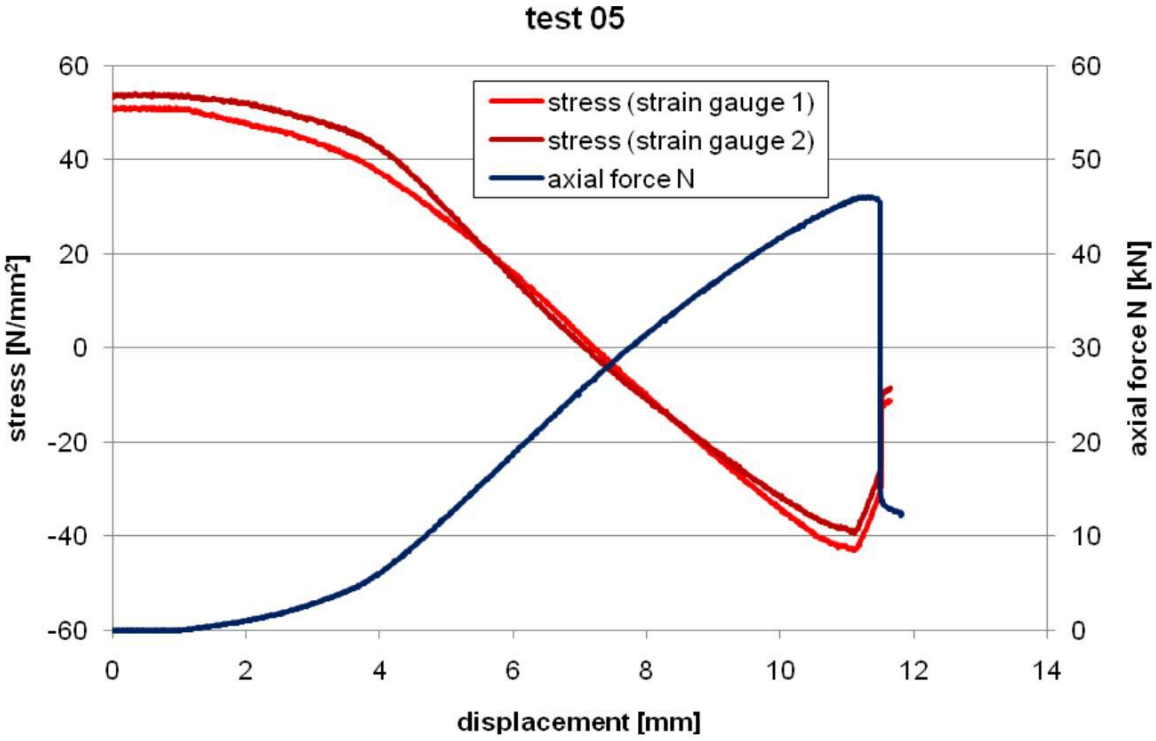
Initial deflection at mid-span w_0: 15 mm

max. axial load N:	46,2 kN
mode of failure:	Shear failure of the core at load introduction

remarks:







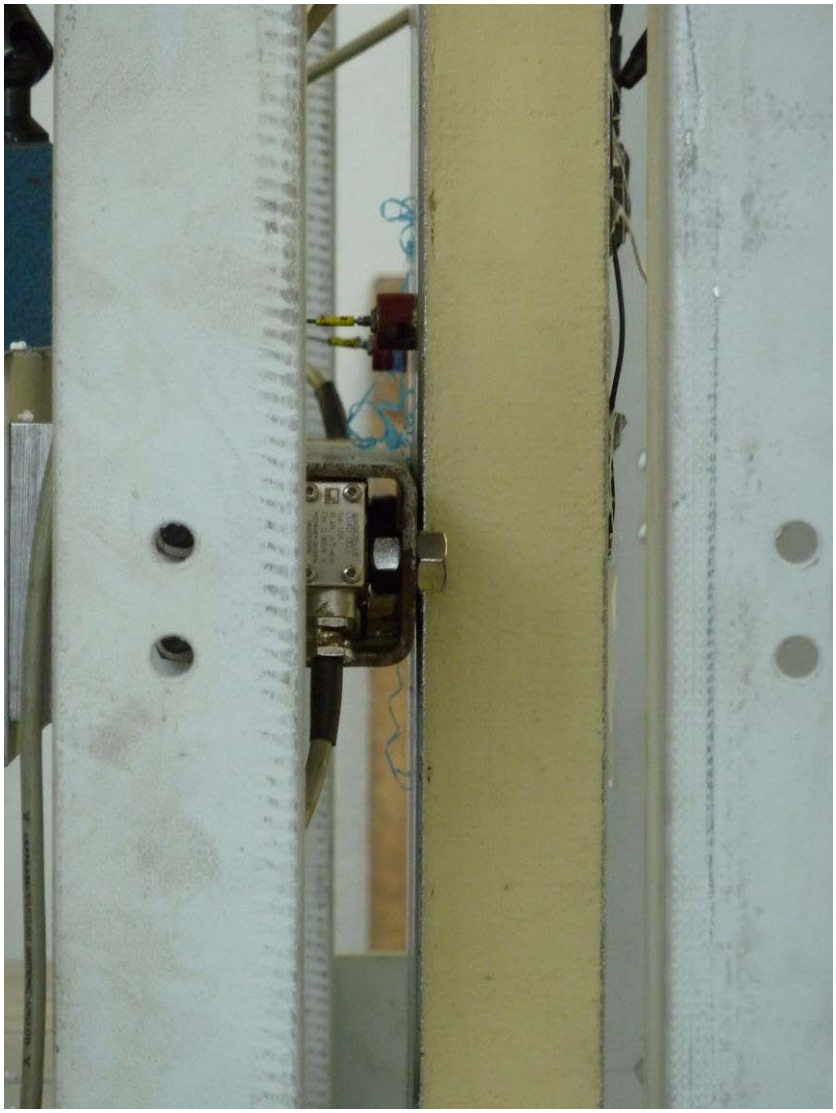


Fig. 13: support in mid-span during test no. 05

Fig. 14: Failure mode of test no. 05

No. 06

type of panel:	F
length of panel:	3000 mm
face material:	steel
face thickness:	0,75 / 0,75 mm
core material:	PU
core thickness:	60 mm

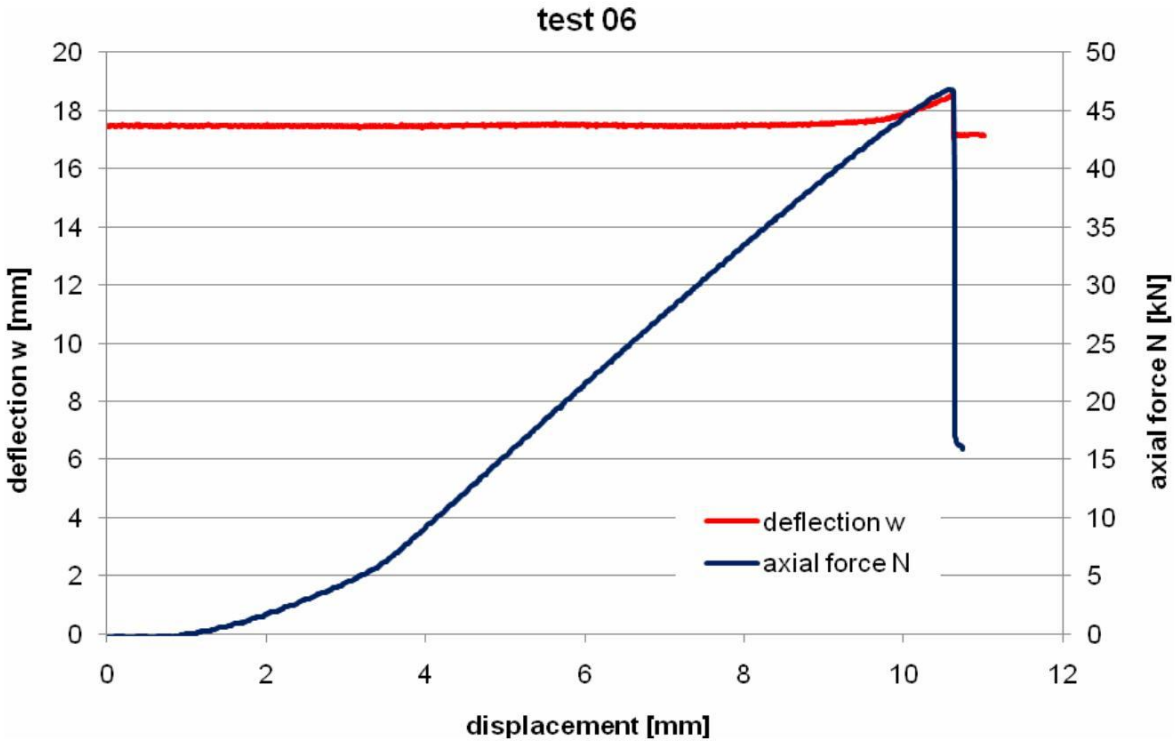
Measured dimensions

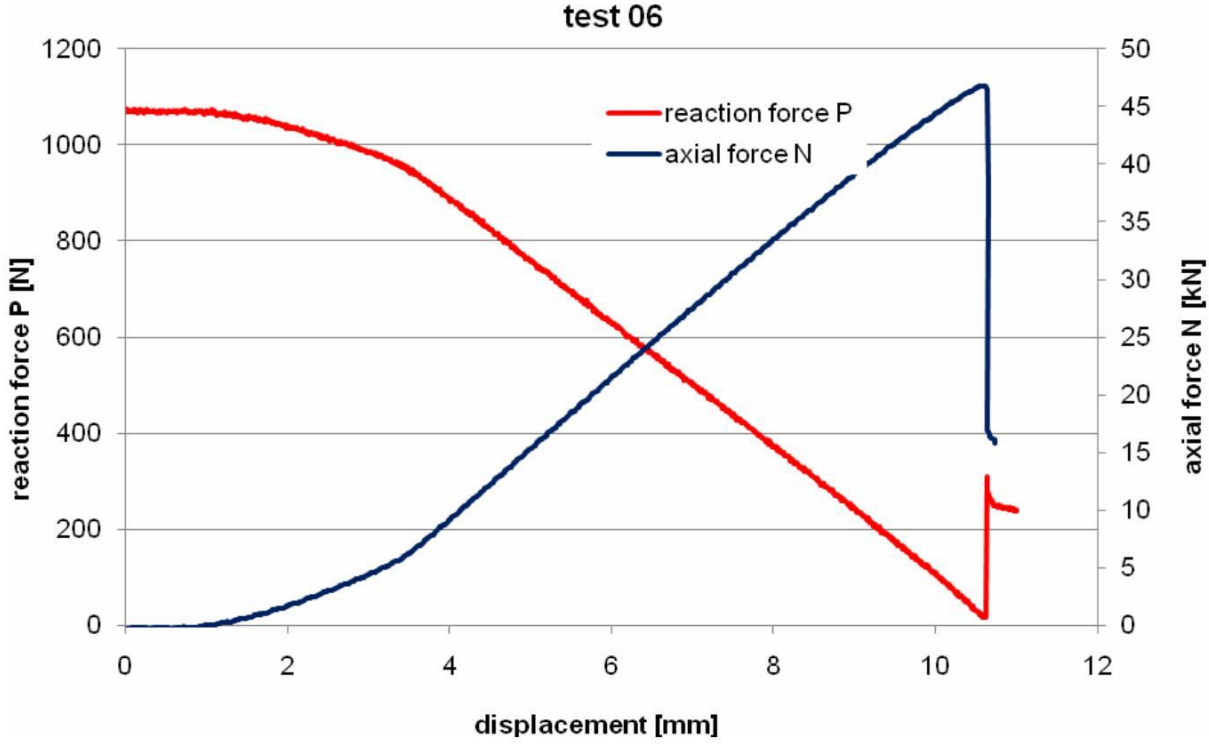
length L:	3043 mm
thickness of the panel B:	60,97 mm / 60,36 mm
width of the panel:	401 mm

Initial deflection at mid-span w_0: 17,5 mm

max. axial load N:	47,0 kN
mode of failure:	Shear failure of the core at load introduction

remarks:





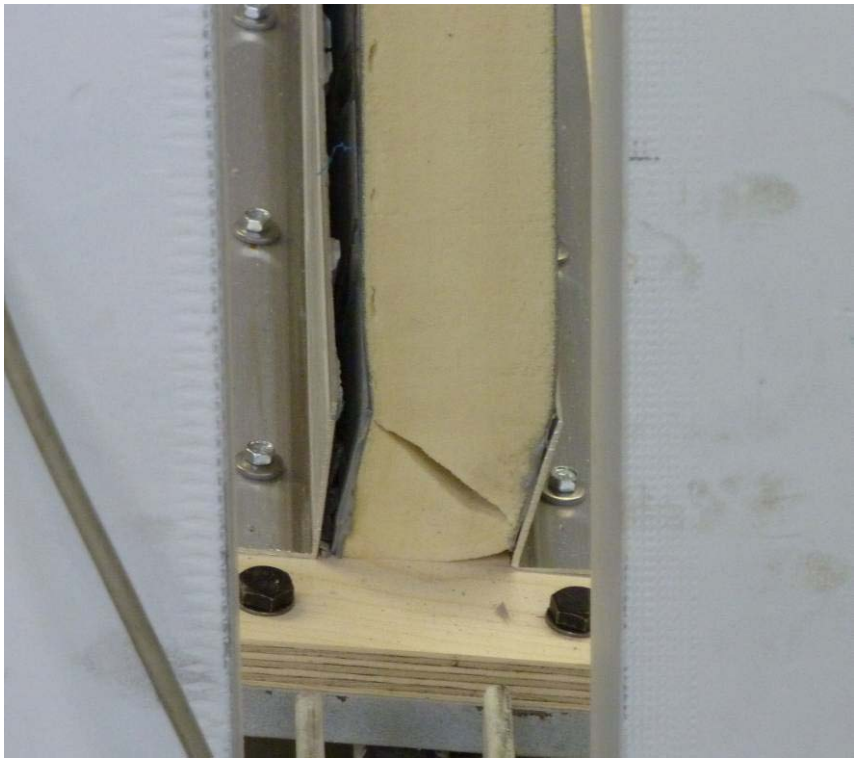


Fig. 15: Failure mode of test no. 06

No. 07

type of panel:	F
length of panel:	3500 mm
face material:	steel
face thickness:	0,75 / 0,75 mm
core material:	PU
core thickness:	60 mm

Measured dimensions

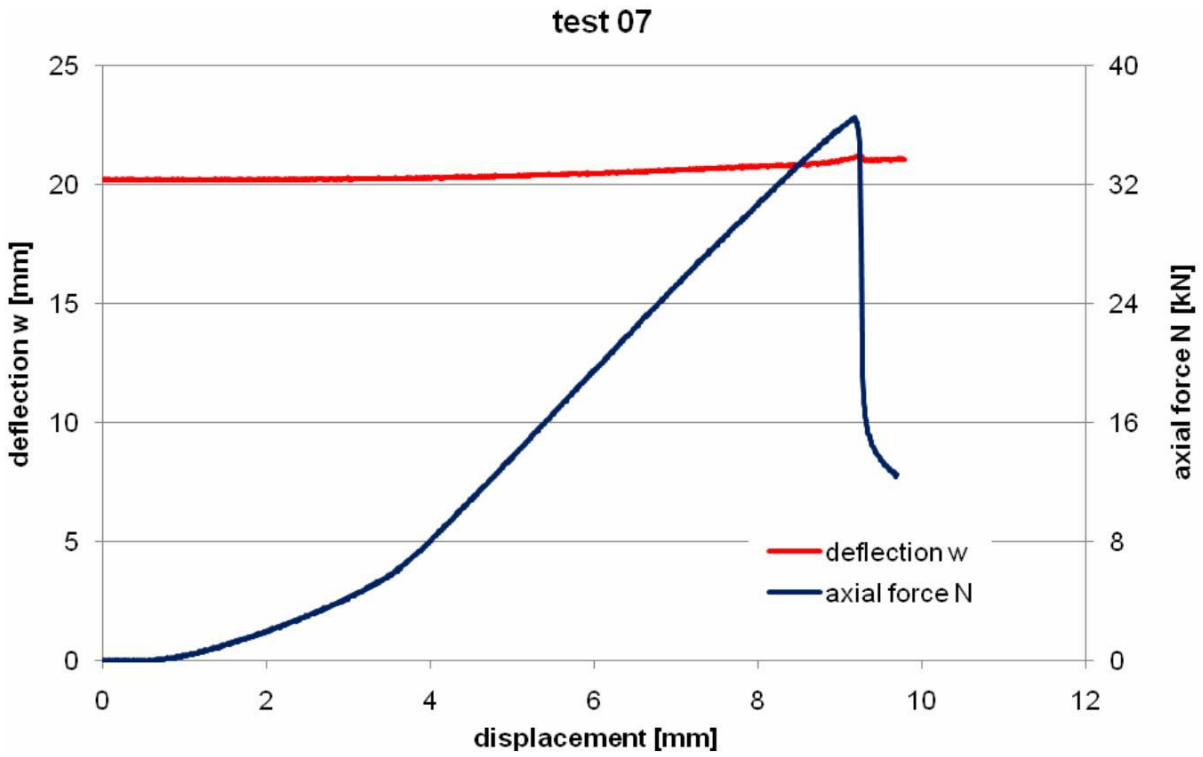
length L:	3548 mm
thickness of the panel B:	60,20 mm / 60,37 mm
width of the panel:	402 mm

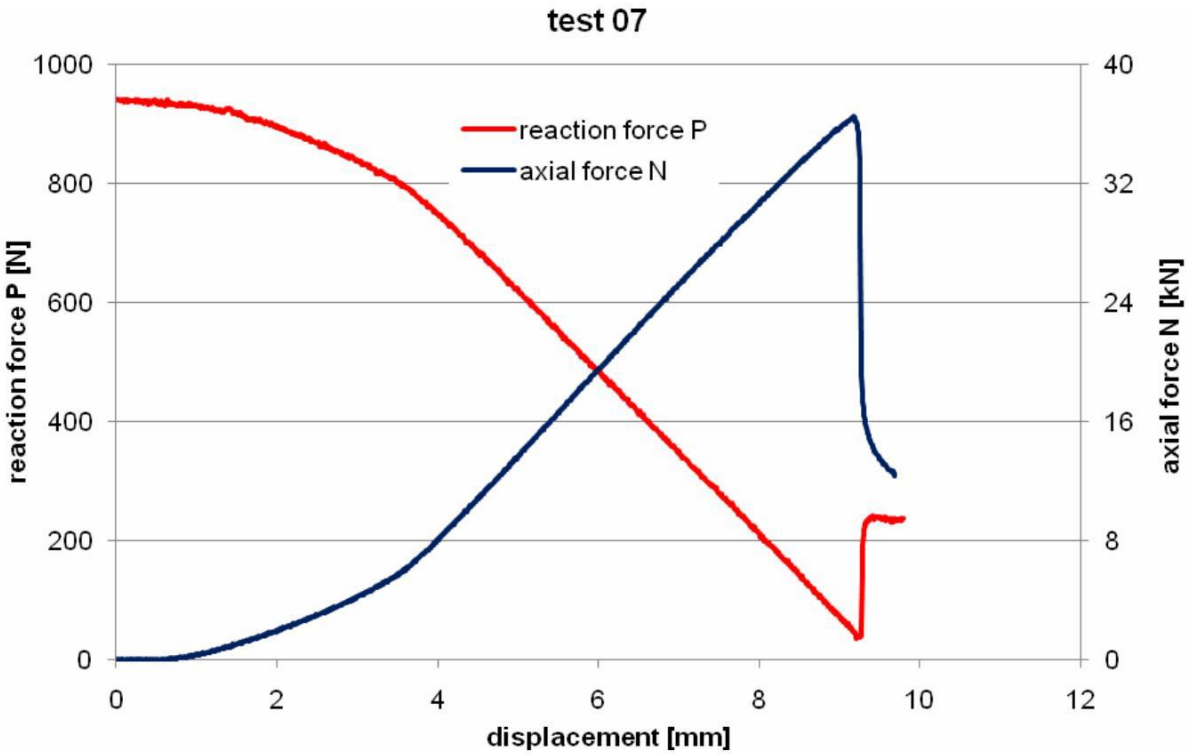
Initial deflection at mid-span w_0: 20 mm

max. axial load N: 36,7 kN

mode of failure: Shear failure of the core at load introduction

remarks:





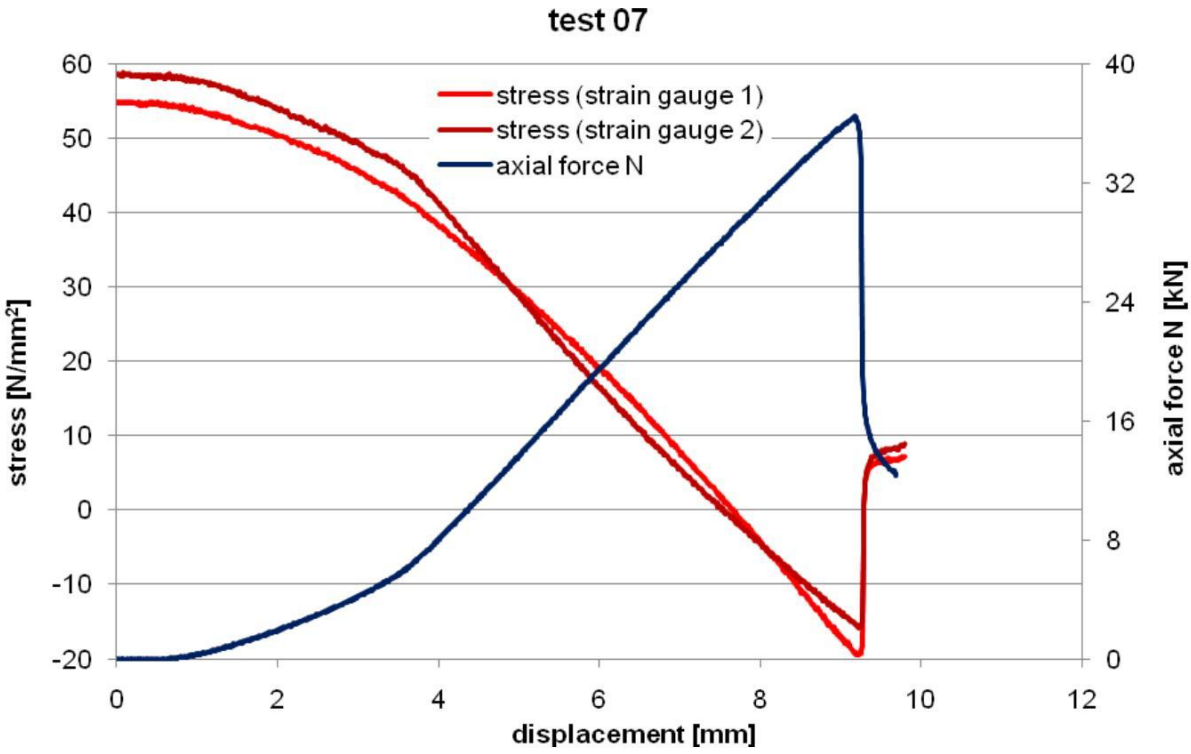


Fig. 16: Failure mode of test no. 07

No. 08

type of panel:	F
length of panel:	3500 mm
face material:	steel
face thickness:	0,75 / 0,75 mm
core material:	PU
core thickness:	60 mm

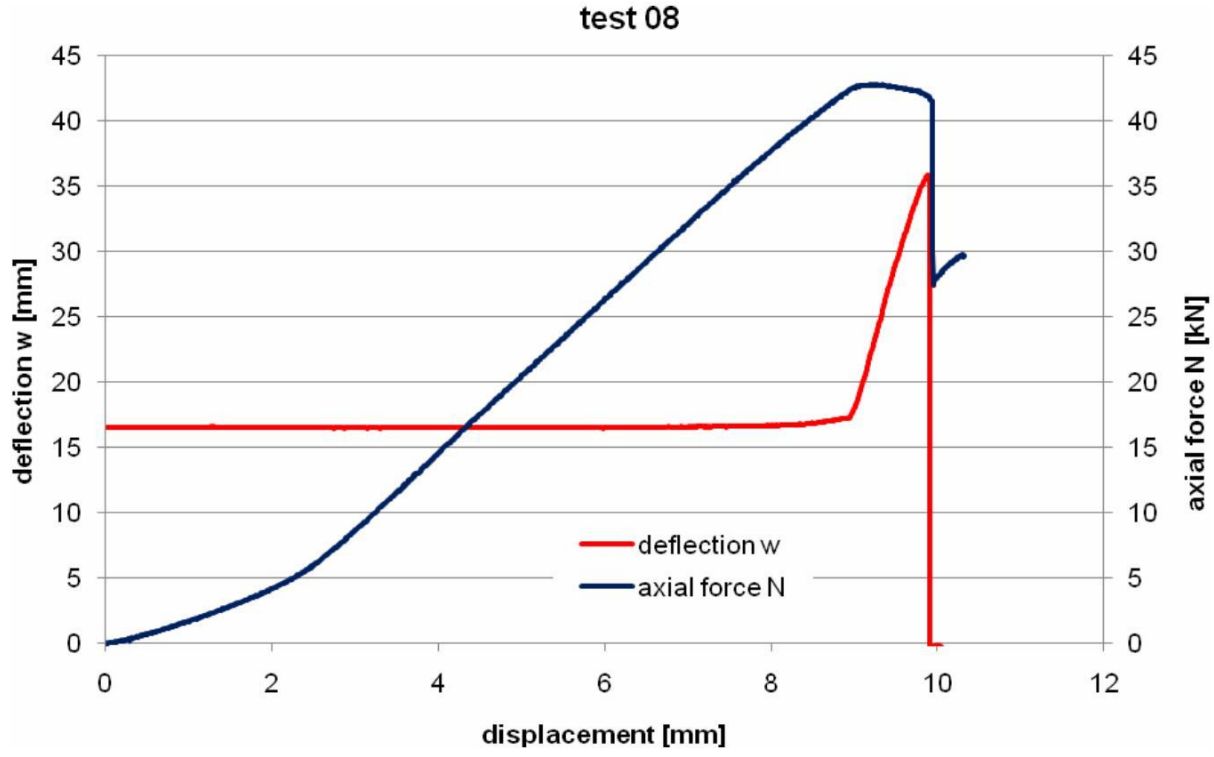
Measured dimensions

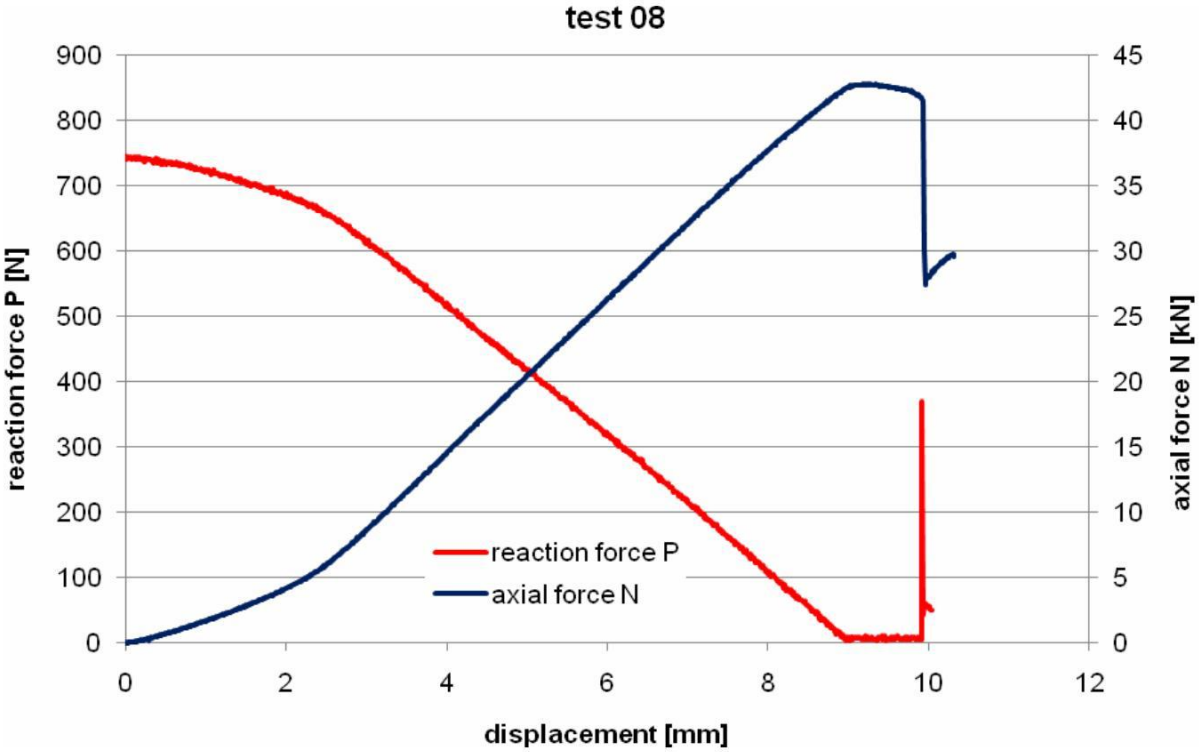
length L:	3555 mm
thickness of the panel B*:	59,66 mm / 59,18 mm
width of the panel:	401 mm

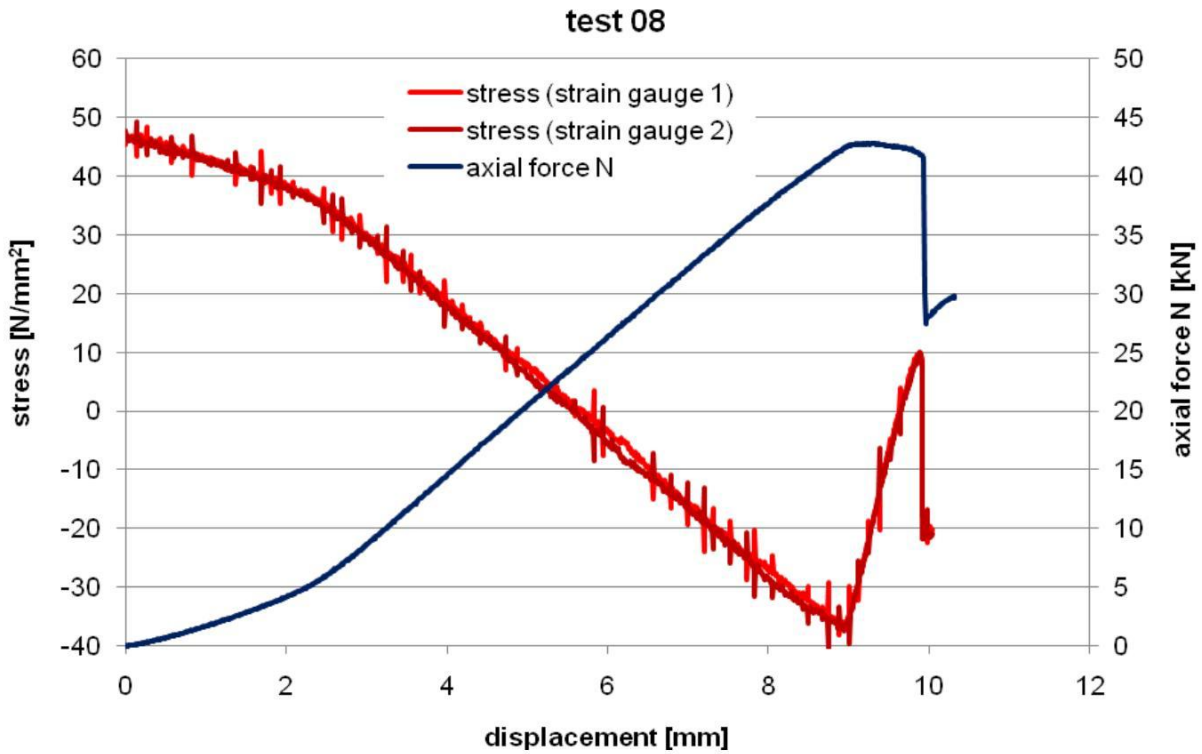
Initial deflection at mid-span w_0:	16,5 mm

max. axial load N:	43,0 kN
mode of failure:	Shear failure of the core at load introduction

remarks:







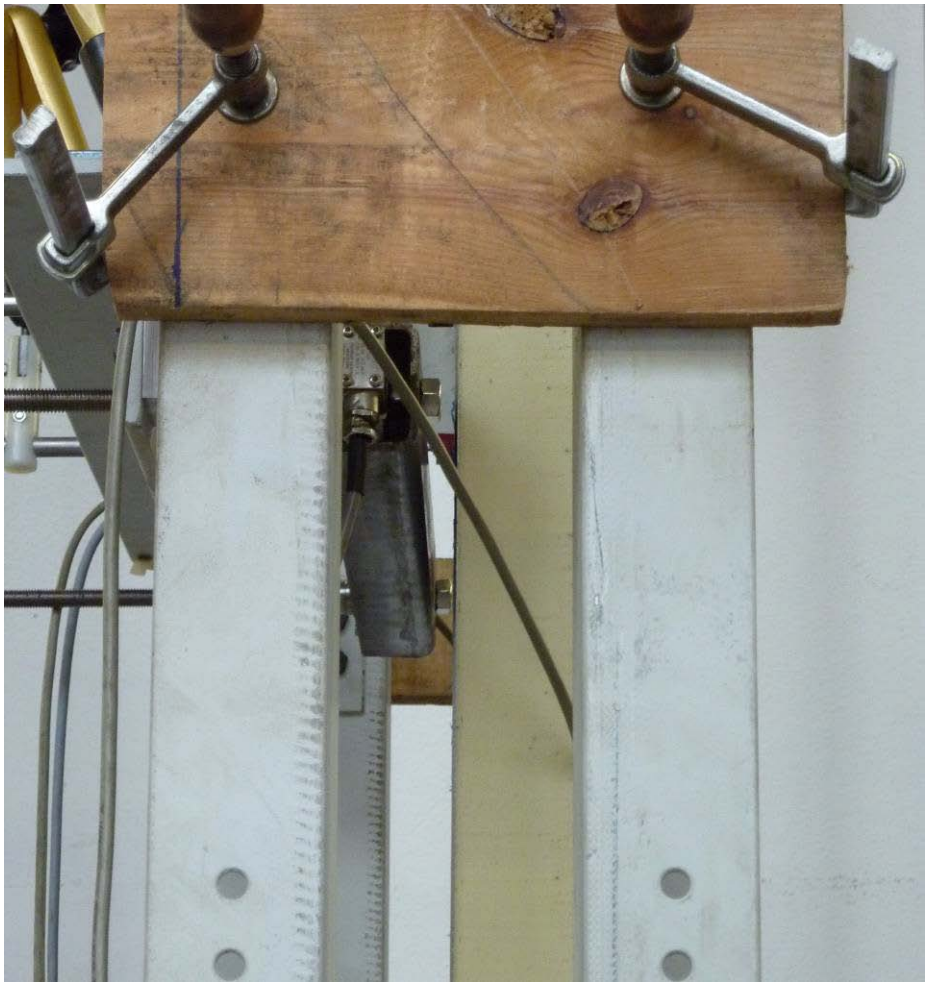


Fig. 17: support in mid-span during test no. 08

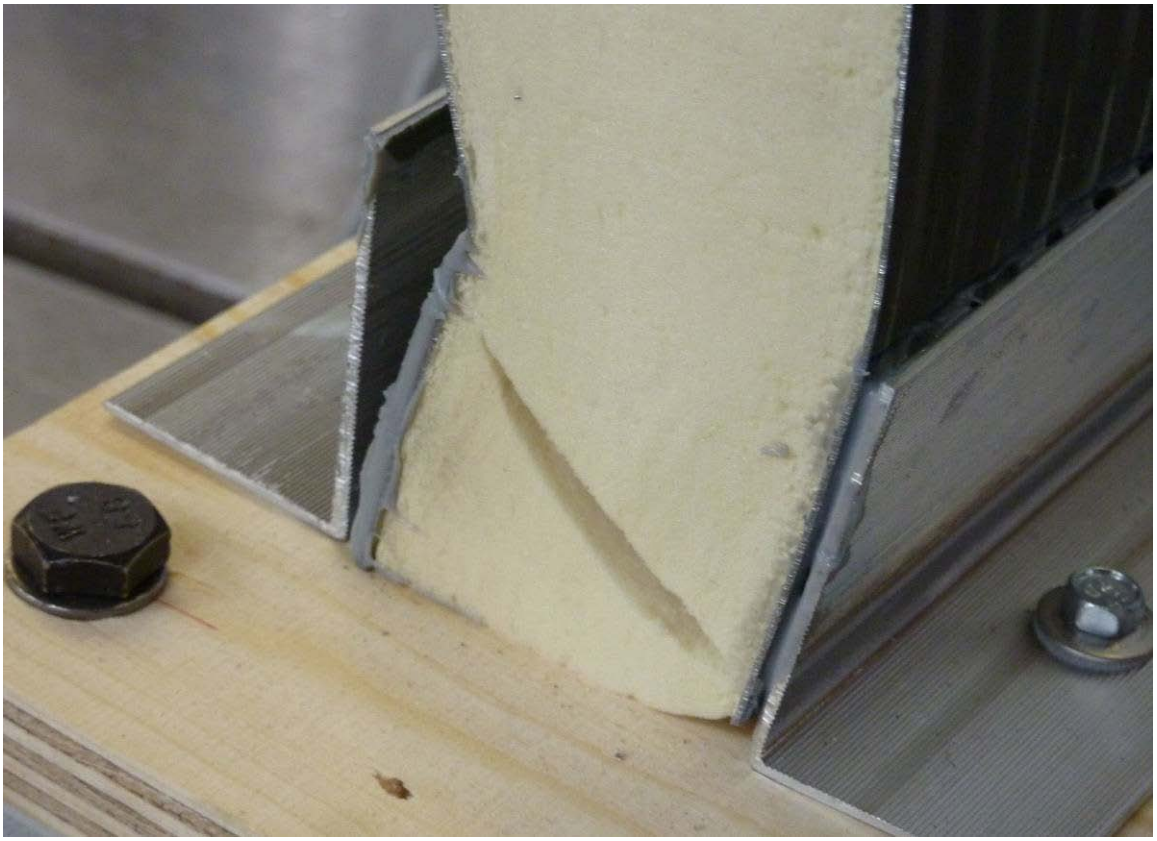


Fig. 18: Failure mode of test no. 08

No. 09

type of panel:	F
length of panel:	3500 mm
face material:	steel
face thickness:	0,75 / 0,75 mm
core material:	PU
core thickness:	60 mm

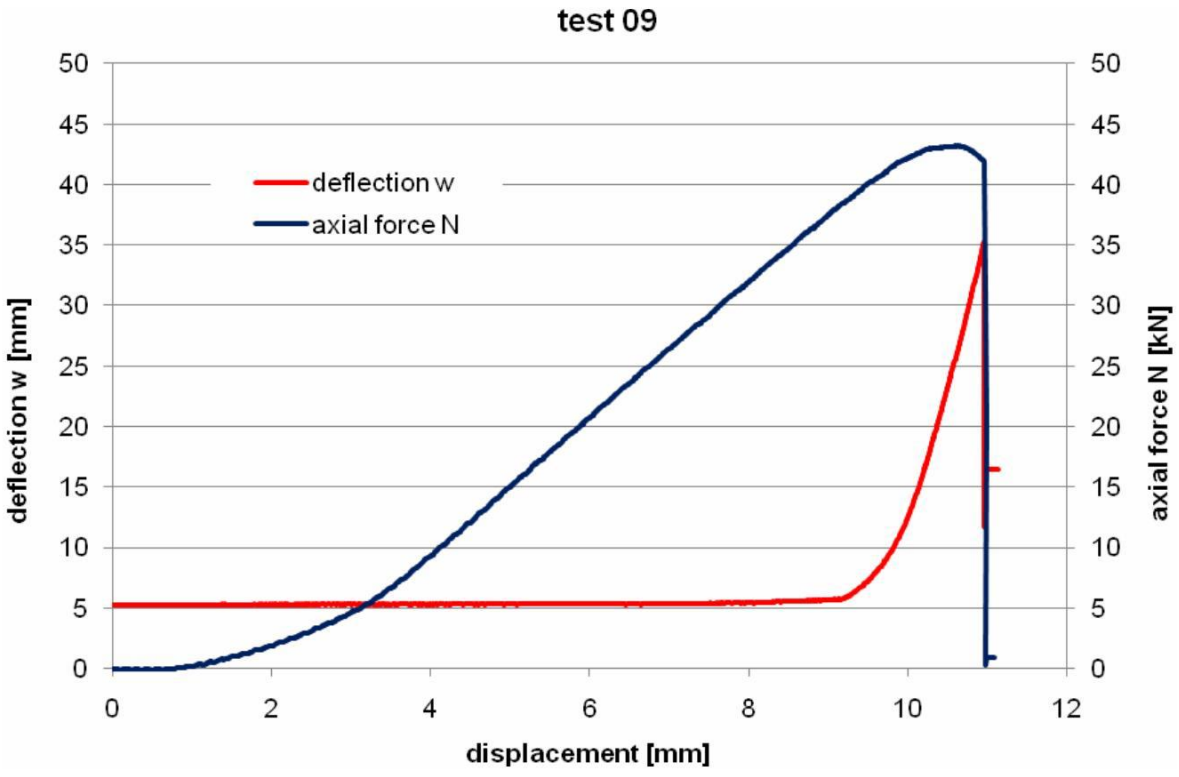
Measured dimensions

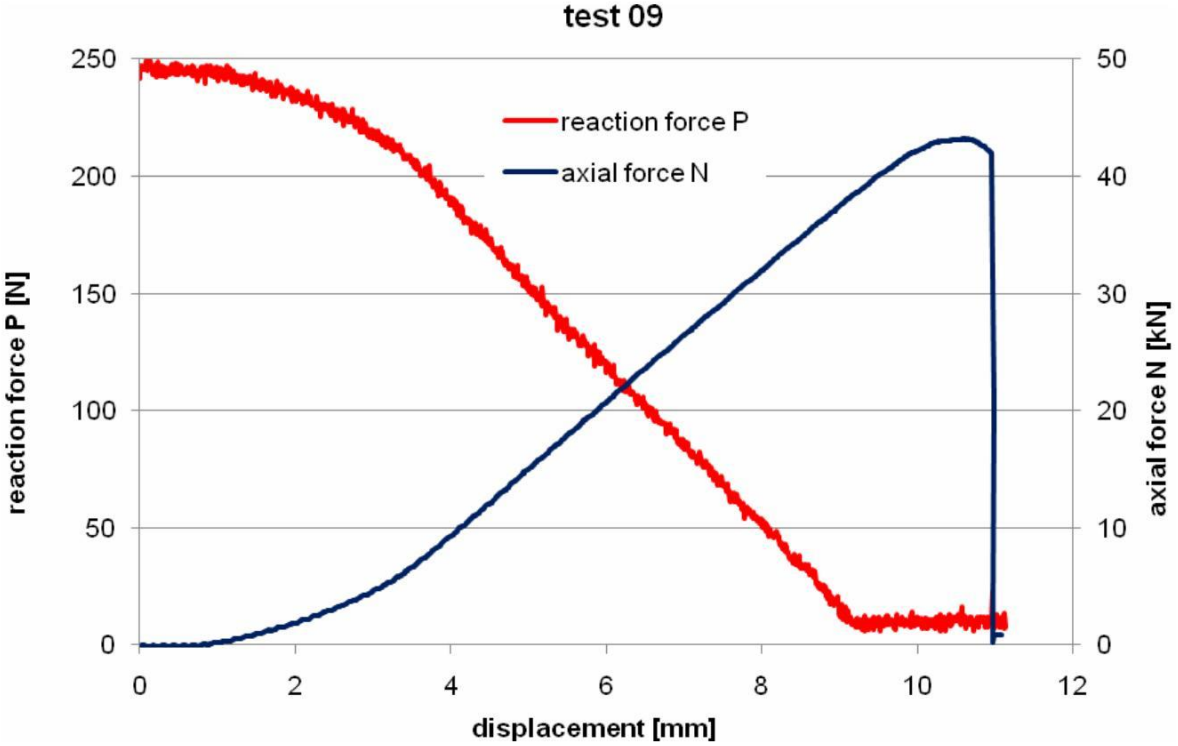
length L:	3545 mm
thickness of the panel B:	60,56 mm / 60,54 mm
width of the panel:	402 mm

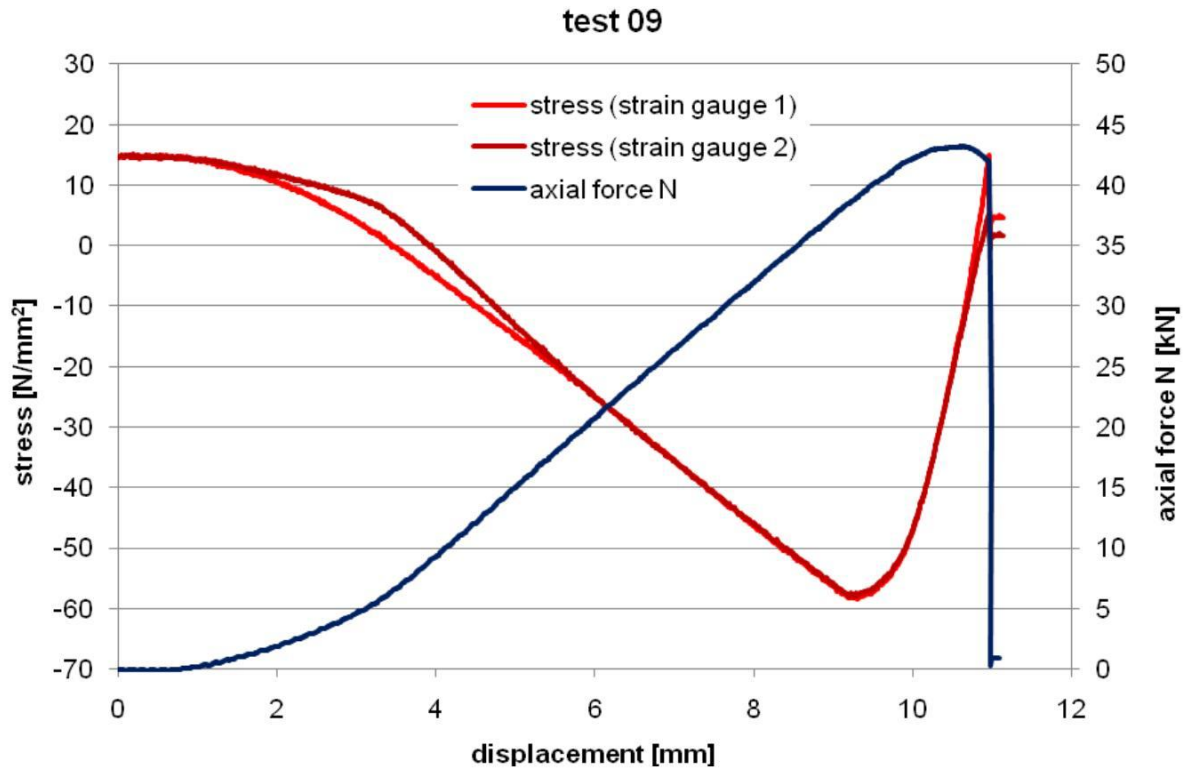
Initial deflection at mid-span w_0: 5 mm

max. Axial load N:	43,4 kN
mode of failure:	Wrinkling of the face subjected to compression

remarks:







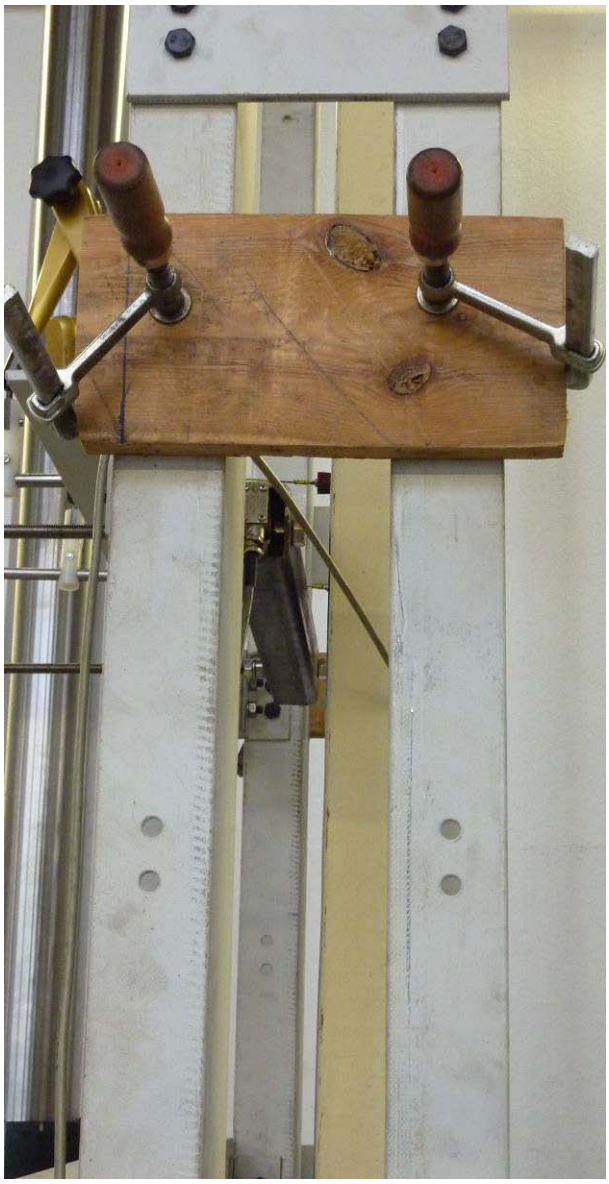


Fig. 19: support in mid-span during test no. 09

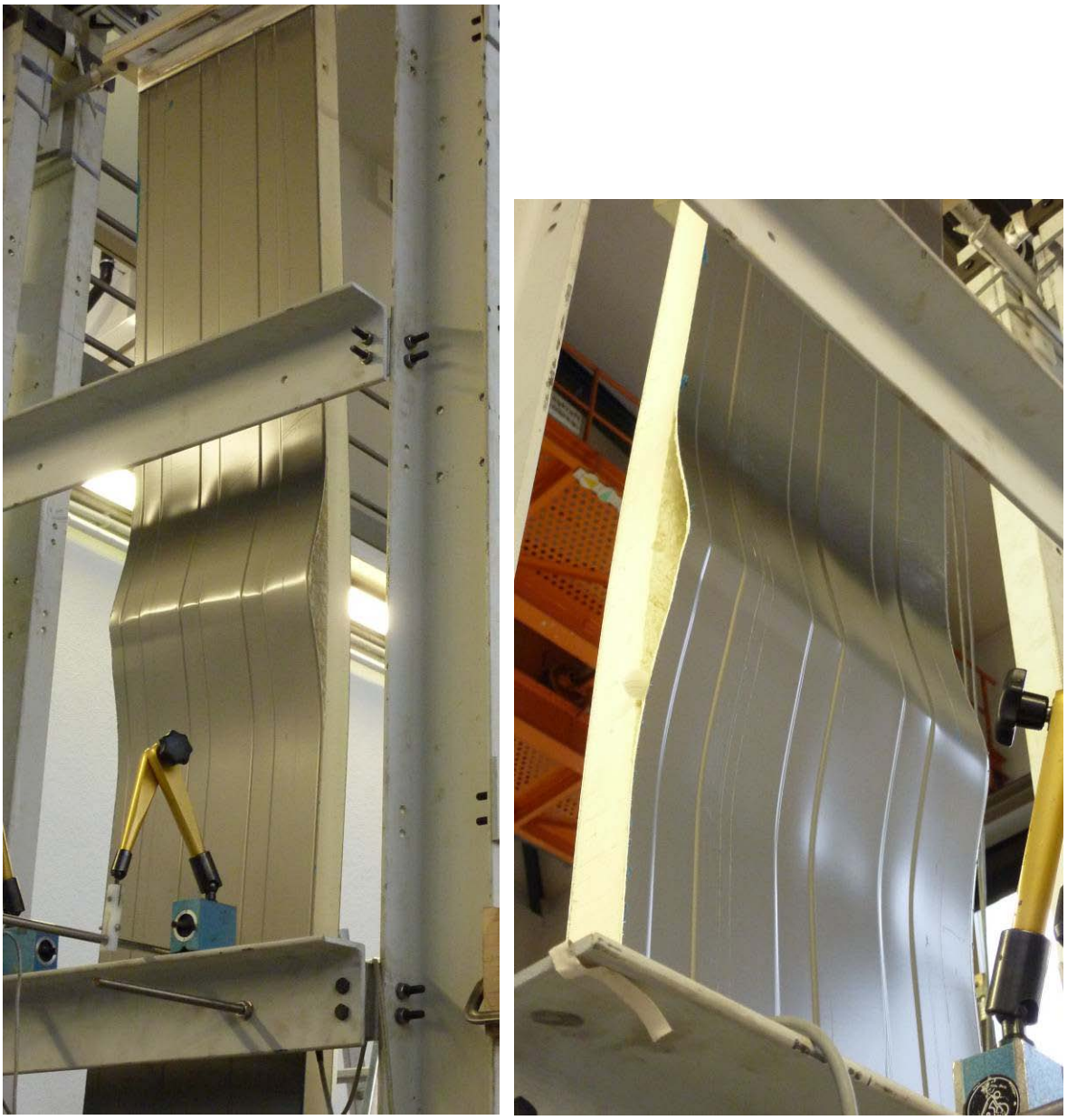


Fig. 20: Failure mode of test no. 09

6 Determination of the material properties

6.1 Core thickness of the metallic surface layers

For each tested type of panel the core thicknesses of the metallic faces were determined. The mean values of the results are listed in Tab. 2.

No.		t_K
		[mm]
F	Face subjected to compression (top side of production)	0,698
	Face subjected to tension (bottom side of production)	0,700
K	Face subjected to compression	0,554
	Face subjected to tension	0,551
L	GFRP	

Tab. 2: Core thickness of the metallic surface layers

6.2 Mechanical properties of the core layer

The mechanical properties were determined according to EN 14509. The determination of the compression strength f_{Cc}, the tensile strength f_{Ct}, the shear strength f_{Cv}, as well as the appropriate shear, compression and tensile module values G_C, E_{Cc} and E_{Ct} was realized on at least three specimens. The analysis of the modulus of elasticity E_C was realised as mean value from the compression and tensile module of a specimen pair. The mean values of the results are listed in Tab. 3 and Tab. 4.

No.	f_{Cv}	f_{Cc}	f_{Ct}
	[N/mm²]	[N/mm²]	[N/mm²]
F	0,15	0,15	0,13
K	0,14	-	-
L	0,14	-	-

Tab. 3: Mechanical properties of the core layer - strength

No.	G_C	E_{Cc}	E_{Ct}	E_C
	[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]
F	3,81	3,25	4,06	3,66
K	5,57	-	-	-
L	11,08	-	-	-

Tab. 4: Mechanical properties of the core layer – module

6.3 Wrinkling stress

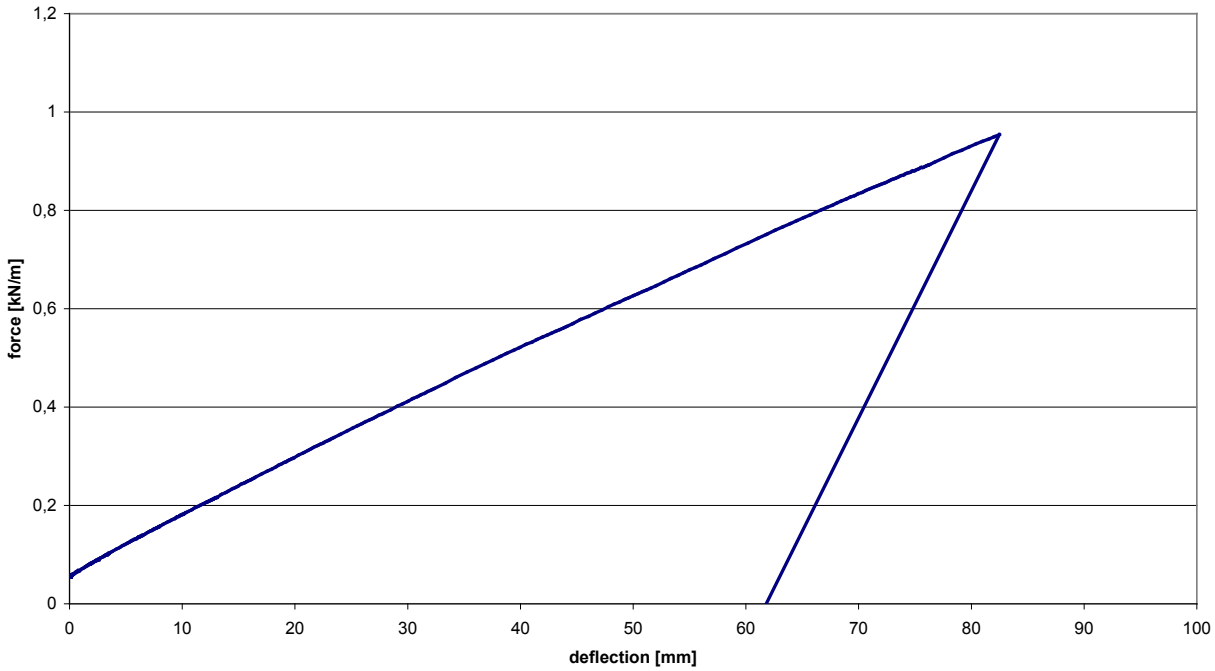
Single-span bending tests were performed with sandwich panels type F. The sandwich panels with a length of 5000 mm were loaded until failure in a vacuum chamber with an effective span of 4800 mm under uniform surface load. For the calculation of the wrinkling stress the measured thickness of the steel faces and the measured thickness of the panels were used. The results of the single-span bending tests are listed in table 5 followed by the load-deflection-diagrams.

test no.	thickness of panel (mean value)	width of specimen	span	core sheet thickness of face subjected to com-pression	failure load incl. dead weight	wrinkling stress
	[mm]	[mm]	[mm]	[mm]	[kN/m]	[N/mm²]
	D	B	l_a	t_K	p	σ_w
WS 1 [1)]	60,5	400	4800	0,698	0,95	165
WS 2 [2)]	60,5	402	4800	0,700	1,24	213

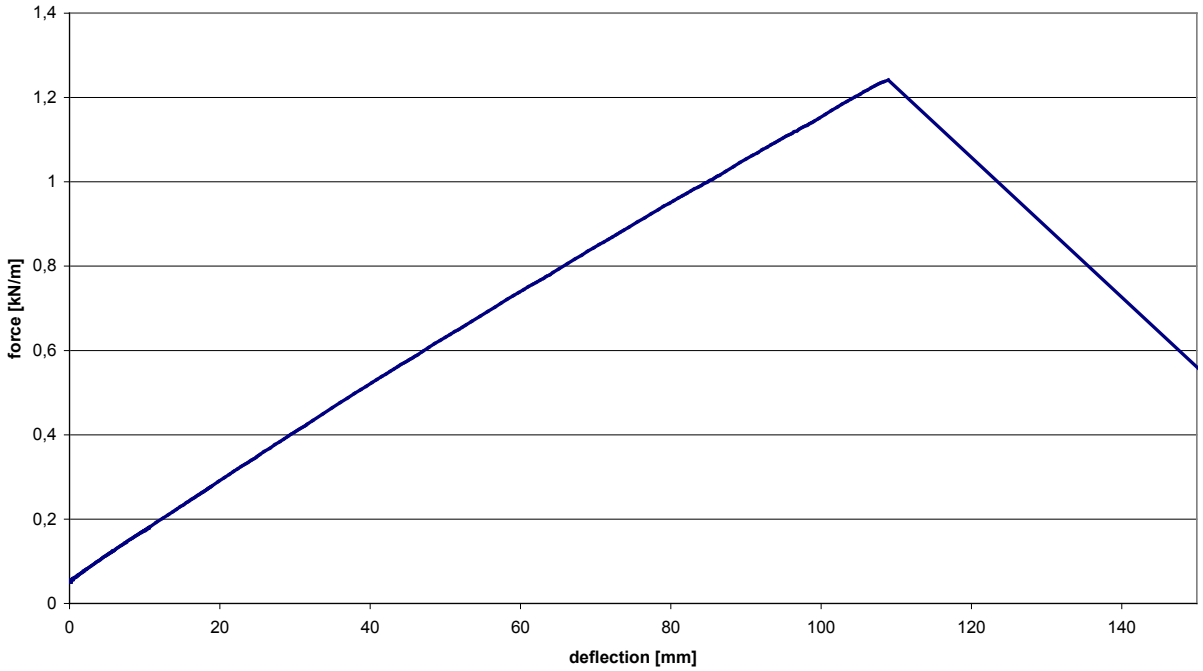
[1)] top side of production subjected to compression
[2)] bottom side of production subjected to compression

Tab. 5: Wrinkling stress of the faces

test WS 1



test WS 2



7 Summary

WP 3, task 3.4 of the EASIE project deals with sandwich panels used for buildings without substructure. In this application the wall panels have to transfer normal forces in addition to transverse loads. In deliverable 3.2 – part 3 the results of the experimental tests on axially loaded sandwich panels are presented.