Ensuring Advancement in Sandwich Construction Through Innovation and Exploitation

TEST REPORT

No.: D3.2 – part 4

Creeping tests on axially loaded sandwich panels

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Task:	3.4
Object:	Creeping behaviour of axially loaded sandwich panels

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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 results 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. The developed design concept also includes long term effects. In deliverable D3.2 – part 4, the results of the experimental tests on the creep behaviour of axially 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). For all tests specimens with the width 400 mm and the length 3000 mm have been used.

No.	Core material	Core thickness	Face material	Face thickness	Profiling of faces
F	PUR	60	steel	0,75	lightly profiled
G	EPS	60	steel	0,60	flat
H	EPS	60	GFRP	1,8	flat
I	MW	60	steel	0,60	lightly profiled

Tab. 1: tested types of sandwich panels

The geometry of the panels with profiled faces (type F and I) was measured. The results are shown in the following figures.

Fig. 1: Geometry of panel type F

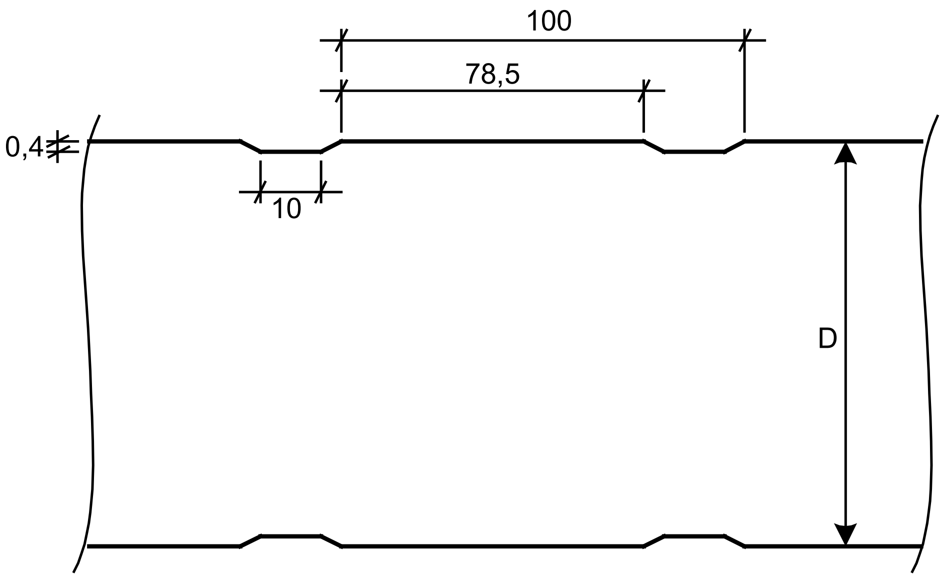


Fig. 2: Geometry of panel type I

3 Test set-up

The test set-up for performing the creep tests on axially loaded sandwich panels is outlined in Fig. 3 and Fig. 4.

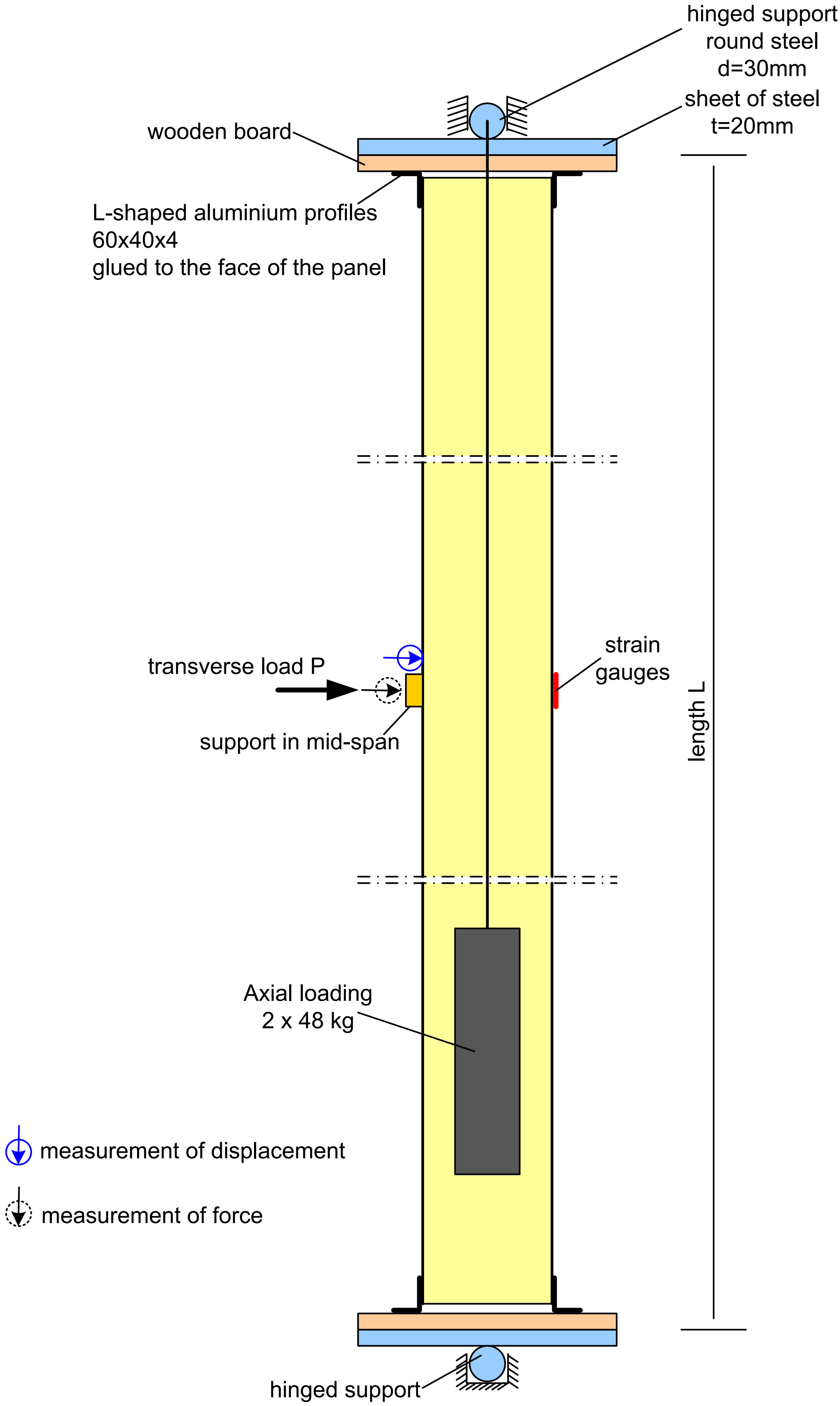


Fig. 3: Test set-up

Fig. 4: Test set-up

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

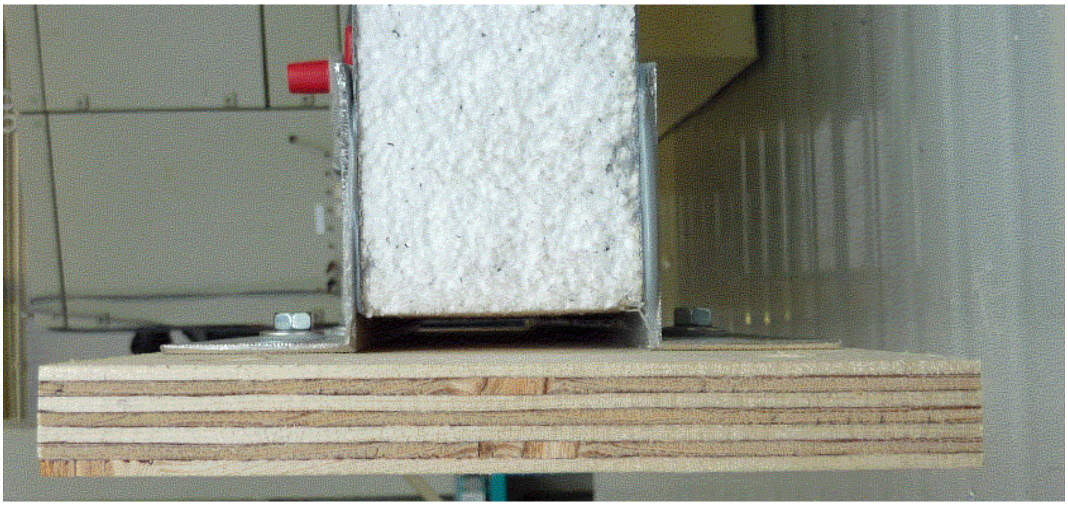


Fig. 5: Load introduction by glued aluminium angles

At the transverse edges of the panel a sheet of steel, which was connected to a round steel, was screwed to the wooden board.
At the lower end of the panel the round steel was used as hinged support. At the top end of the panel the round steel was supported hinged and vertical movable (Fig. 6).

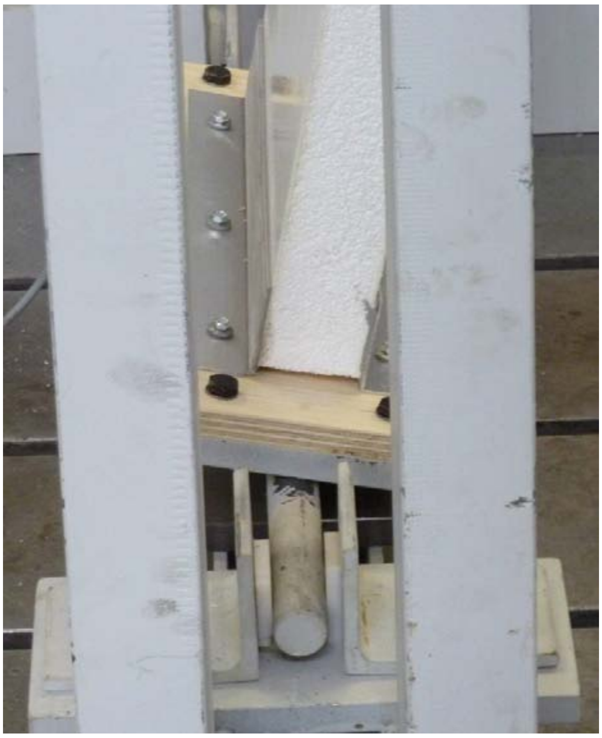


Fig. 6: Hinged support at the lower

The round steel at the top end of the panel was used for introducing the axial force. For each type of panel two tests were performed: In the first test the axial load was applied at the centroidal axis of the panel. In the second test the axial load was applied in only one face.

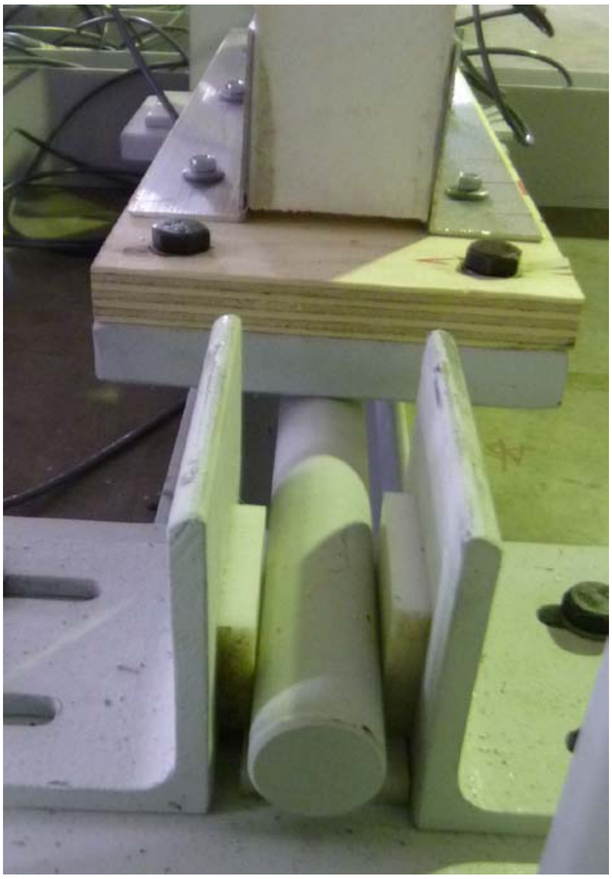


Fig. 7: Centric application of axial force

Fig. 8: Eccentric application of axial force

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 were measured at mid-span (Fig. 9). To measure the reaction force P strain gauges were used which were applied on the thread rods, used to install the support at mid-span (Fig. 10).

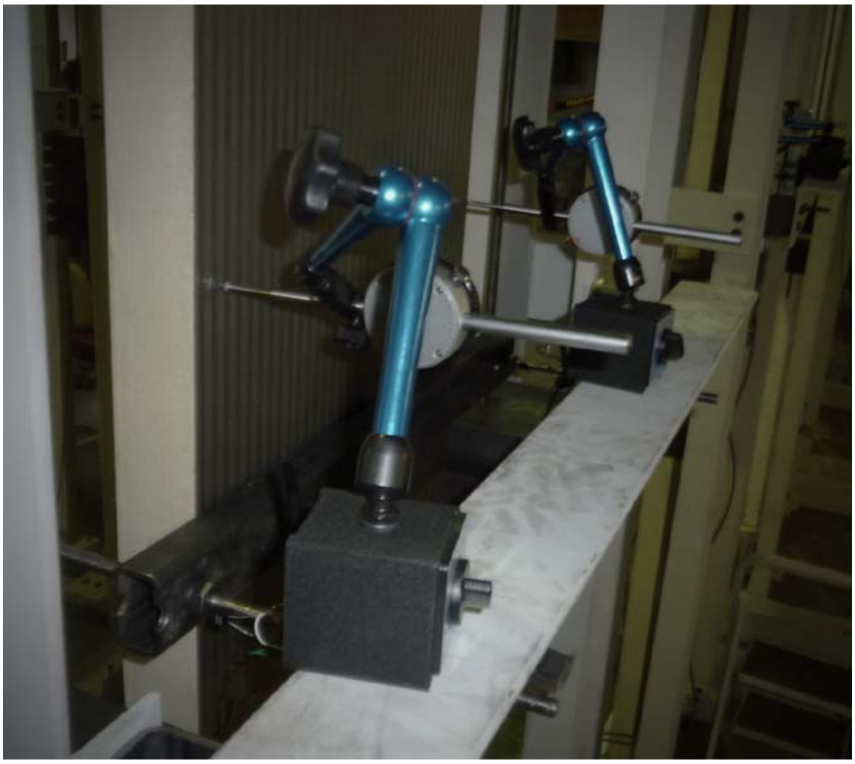


Fig. 9: Measurement of deflection and support at mid-span

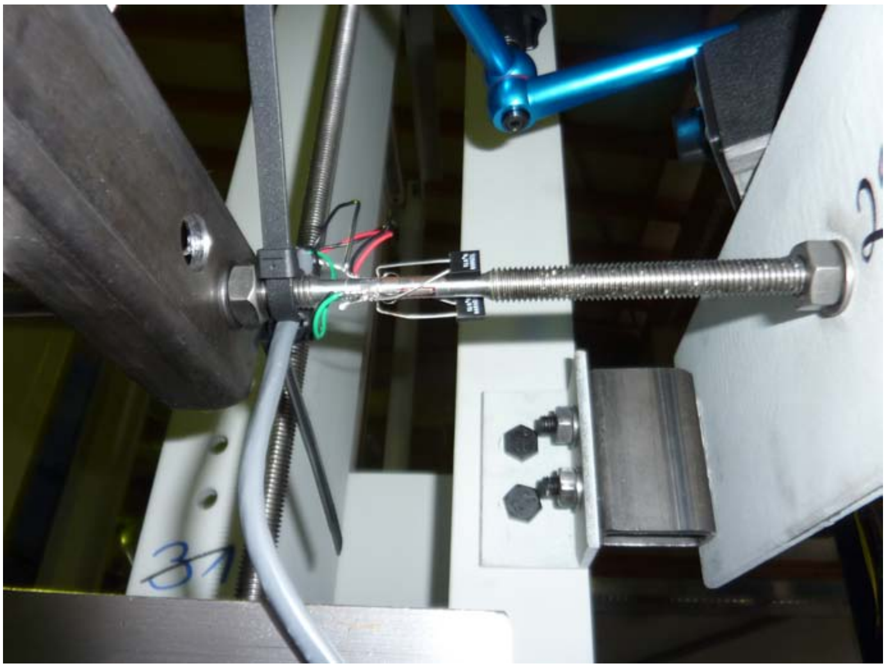


Fig. 10: Strain gauges for measurement of reaction forces at mid-span

At the face subjected to tension two strain gauges were applied in mid-span (Fig. 11).

Fig. 11: Strain gauges at the face of the panel

4 Test performance and results of the tests

At the beginning of the test an axial force of approximately 1kN was applied. Following the initial deflection w_0 was applied to the panel at mid-span. At this position the support was fixed during the test.

The reaction force P in mid-span and the strain in the face subjected to tension were measured continuously during the test.

Annex 1 shows the results of the tests. For each test, a table listing all relevant parameters is given, followed by the graphs of the measured values. The first diagram shows the forces at mid-support for both thread rods. For determination of the forces a load-strain-curve was determined for each thread rod before starting the tests. The second diagram shows the measured strains in the face subjected to tension.

During the test increasing of deflection in mid-span did not appear at any specimen.

5 Creep tests according to EN 14509

For the purpose of comparison additionally to the creep tests on axially loaded panels creep tests with transverse loading according to EN 14509 were performed for each type of panel. The test was performed on simply-supported panels with the span L = 2700 mm which were subjected to a uniformly distributed dead load (Fig. 12, Fig. 13, Tab. 2).

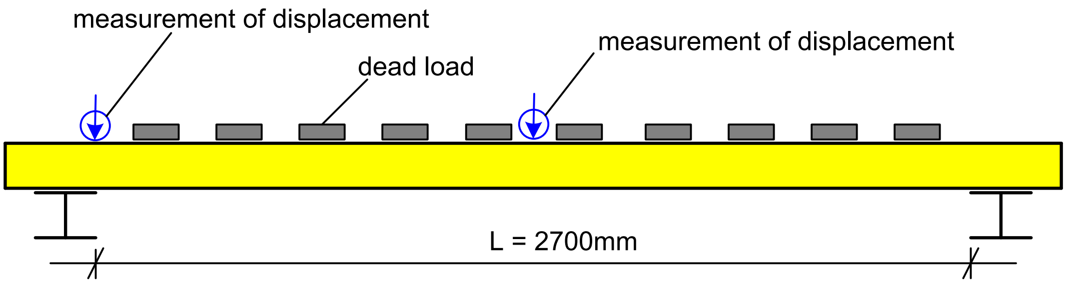


Fig. 12: Test set up of creep tests

Fig. 13: Test set up of creep tests

No.	dead load
F	1,44 kN
G	1,44 kN
H	0,96 kN
I	0,64 kN

Tab. 2: Dead load

In mid-span and at one support line the displacement was regularly measured during the test. Annex 2 shows the results of the tests. For each test, a table listing all relevant parameters is given, followed by the deflection-time-graph. The deflection of the panel was determined by subtracting the displacement at support line from the displacement at mid-span.

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. 3.

No.		t_K
		[mm]
F	Face subjected to tension (top side of production)	0,698
	Face subjected to compression (bottom side of production)	0,700
G	-	0,55
	-	0,54
H	GFRP	
I	-	0,544
	-	0,545

Tab. 3: 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. 4 and Tab. 5.

No.	f_{Cv}	f_{Cc}	f_{Ct}
	[N/mm²]	[N/mm²]	[N/mm²]
F	0,15	0,15	0,13
G	0,15	-	-
H	0,14	-	-
I	0,04	0,10	0,03

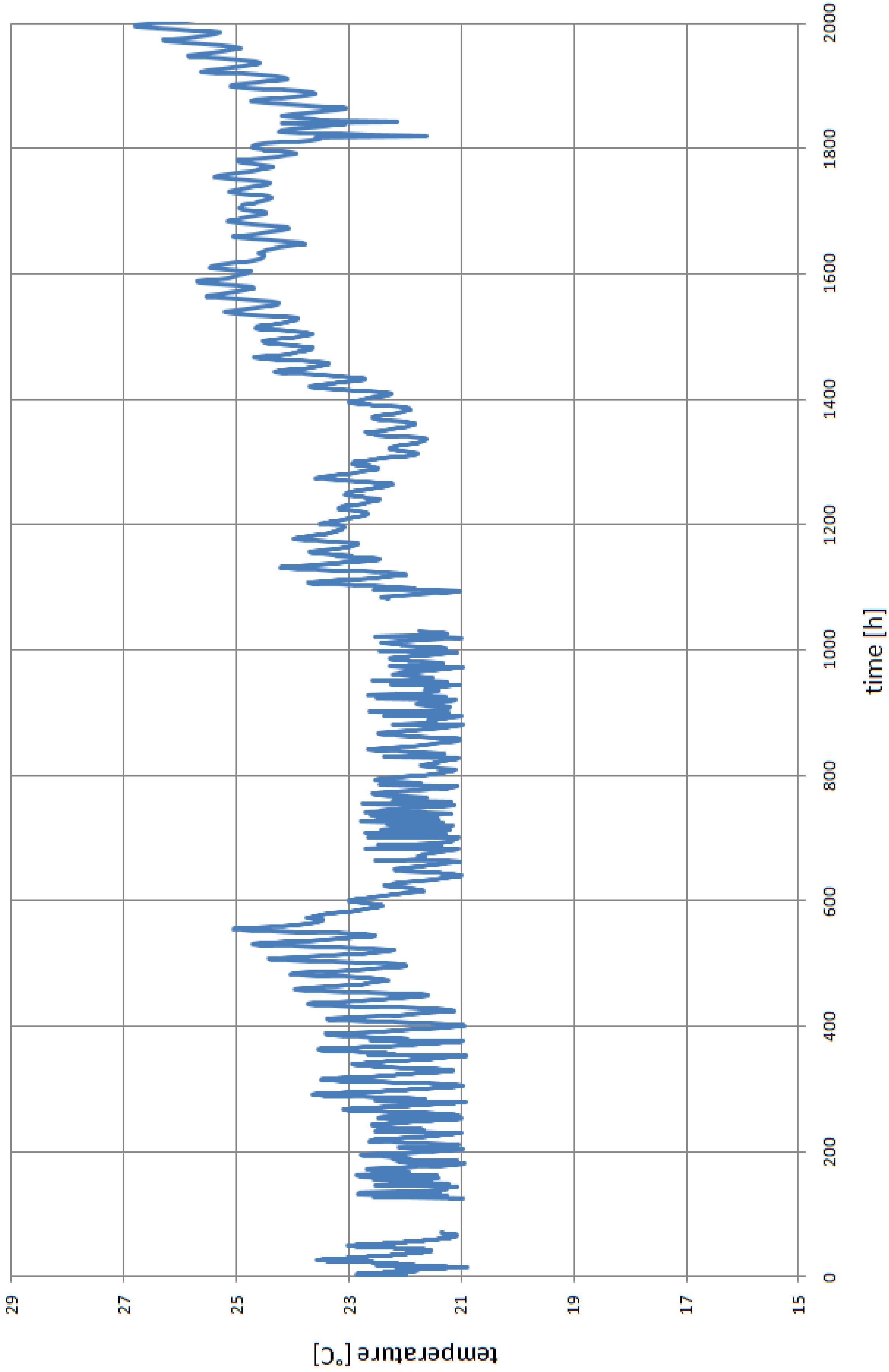
Tab. 4: Mechanical properties of the core layer - strength

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
G	5,89	-	-	-
H	8,27	-	-	-
I	2,31	3,22	4,40	3,81

Tab. 5: Mechanical properties of the core layer – module

7 Ambient temperature

During the test the ambient temperature was measured continuously. The measured temperatures are shown in the following diagram.


time [h]
temperature [°C]
0
200
400
600
800
1000
1200
1400
1600
1800
2000
29
27
25
23
21
19
17
15

8 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 4 the results of the experimental tests on the creep behaviour of axially loaded sandwich panels are presented.

No. F-1

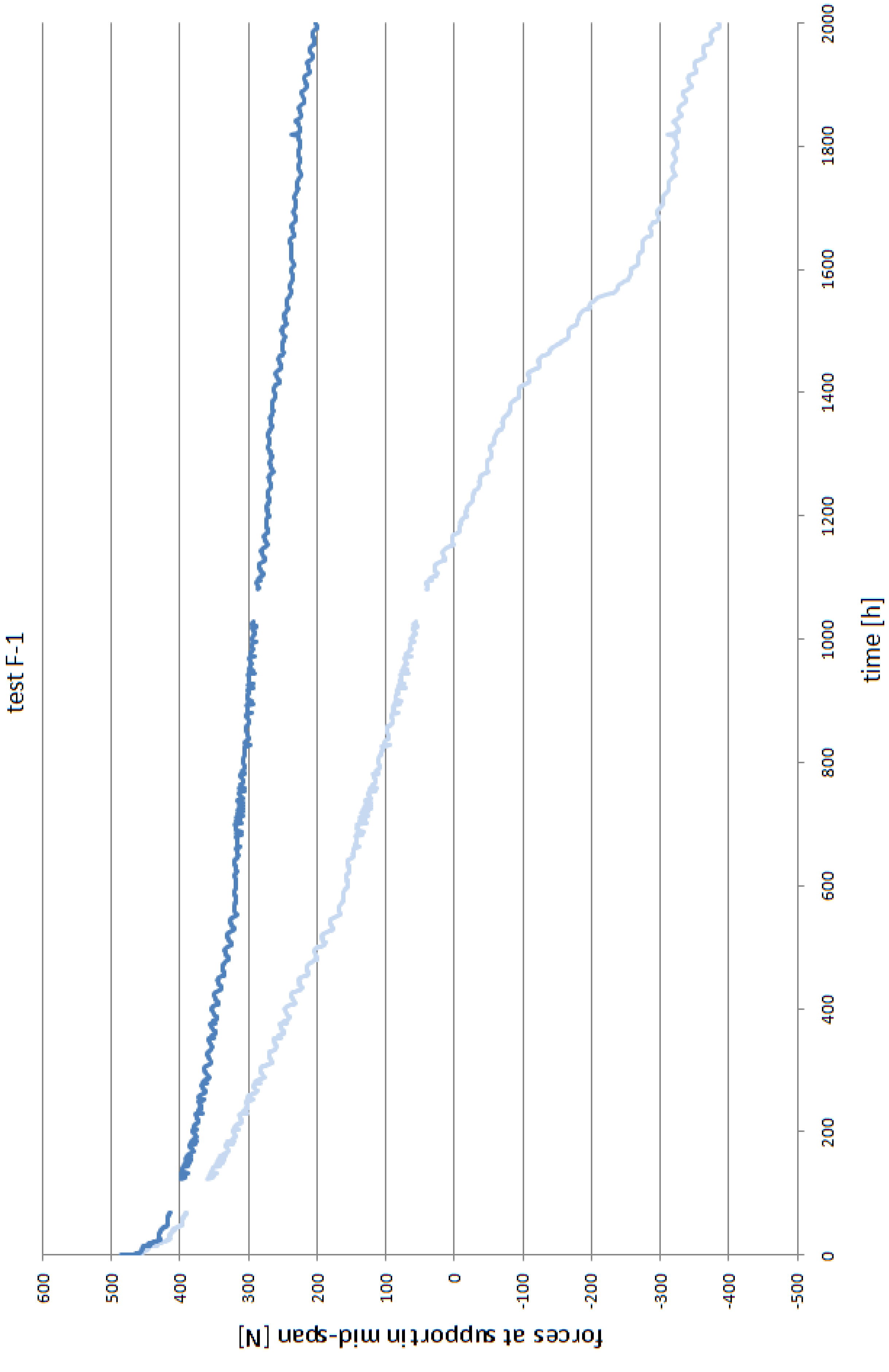
type of panel:	F
application of axial load	centric
face material:	steel
face thickness:	0,75 / 0,75 mm
core material:	PU
core thickness:	60 mm

Measured dimensions

width of the panel:	401
thickness of the panel D:	60,3 mm
length L:	3051 mm

Initial deflection at mid-span: 15,5 mm

remarks: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forces at support in mid-span [N]
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
time [h]
0
200
400
600
800
1000
1200
1400
1600
1800
2000


test F-1
measured strain [µm/m]
time [h]
0
50
100
150
200
250
300
350
0
200
400
600
800
1000
1200
1400
1600
1800
2000

No. F-2

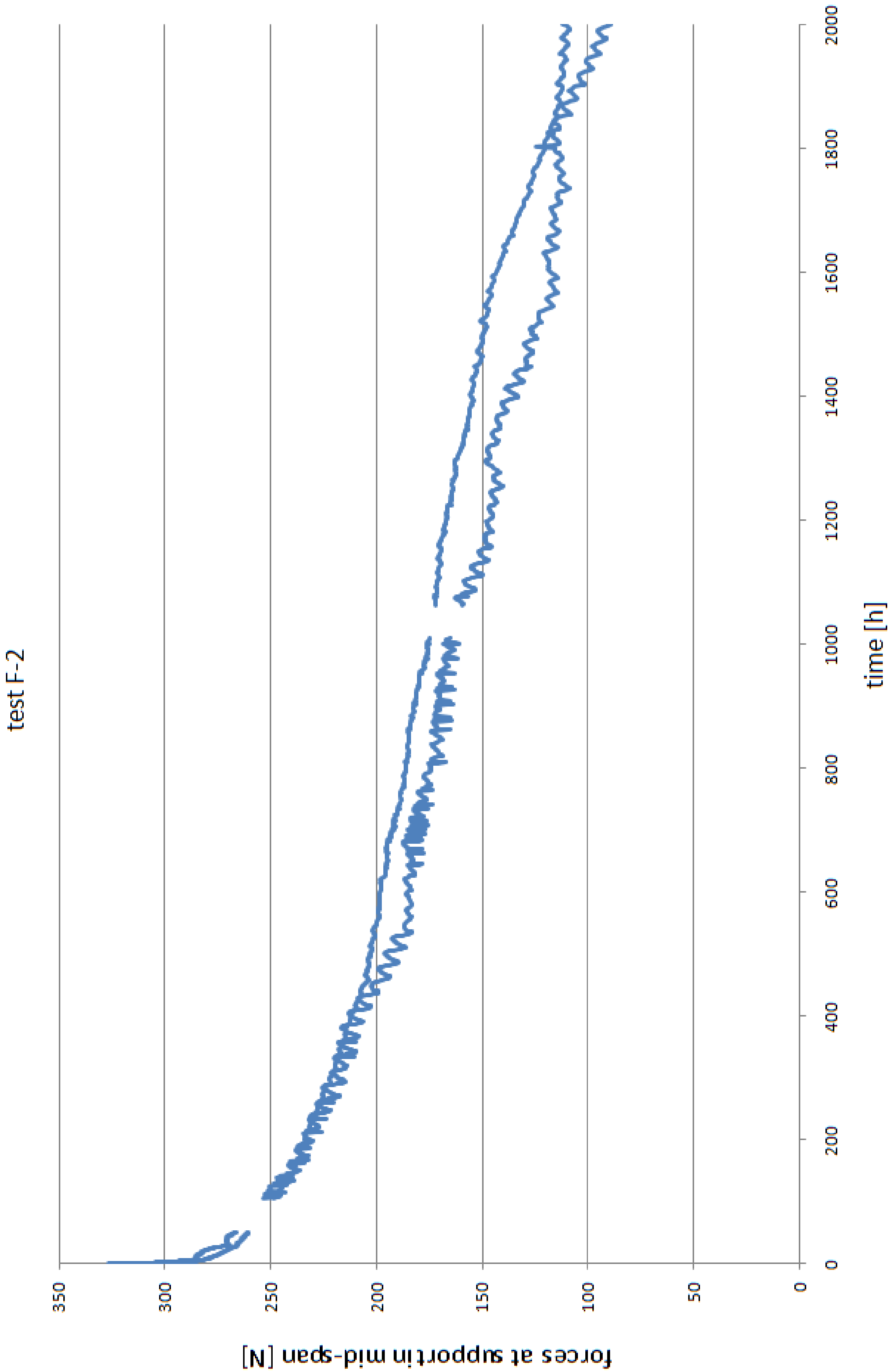
type of panel:	F
application of axial load	eccentric
face material:	steel
face thickness:	0,75 / 0,75 mm
core material:	PU
core thickness:	60 mm

Measured dimensions

width of the panel:	402 mm
thickness of the panel D:	60,6 mm
length L:	3044 mm

Initial deflection at mid-span:	10,5 mm

remarks: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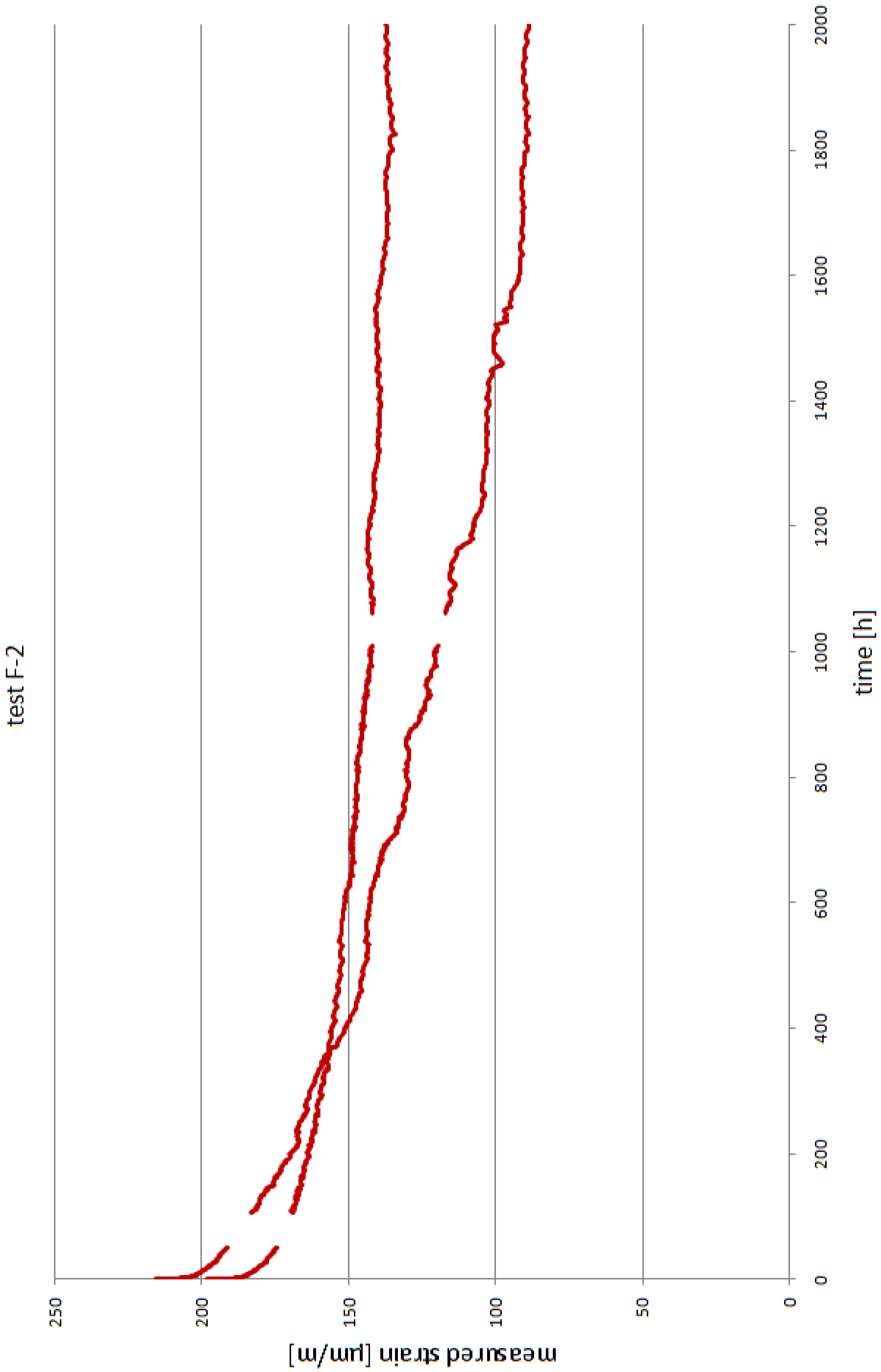
time [h]
forces at support in mid-span [N]
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
50
100
150
200
250
300
350


test F-2
measured strain [µm/m]
0
50
100
150
200
250
time [h]
0
200
400
600
800
1000
1200
1400
1600
1800
2000

No. G-1

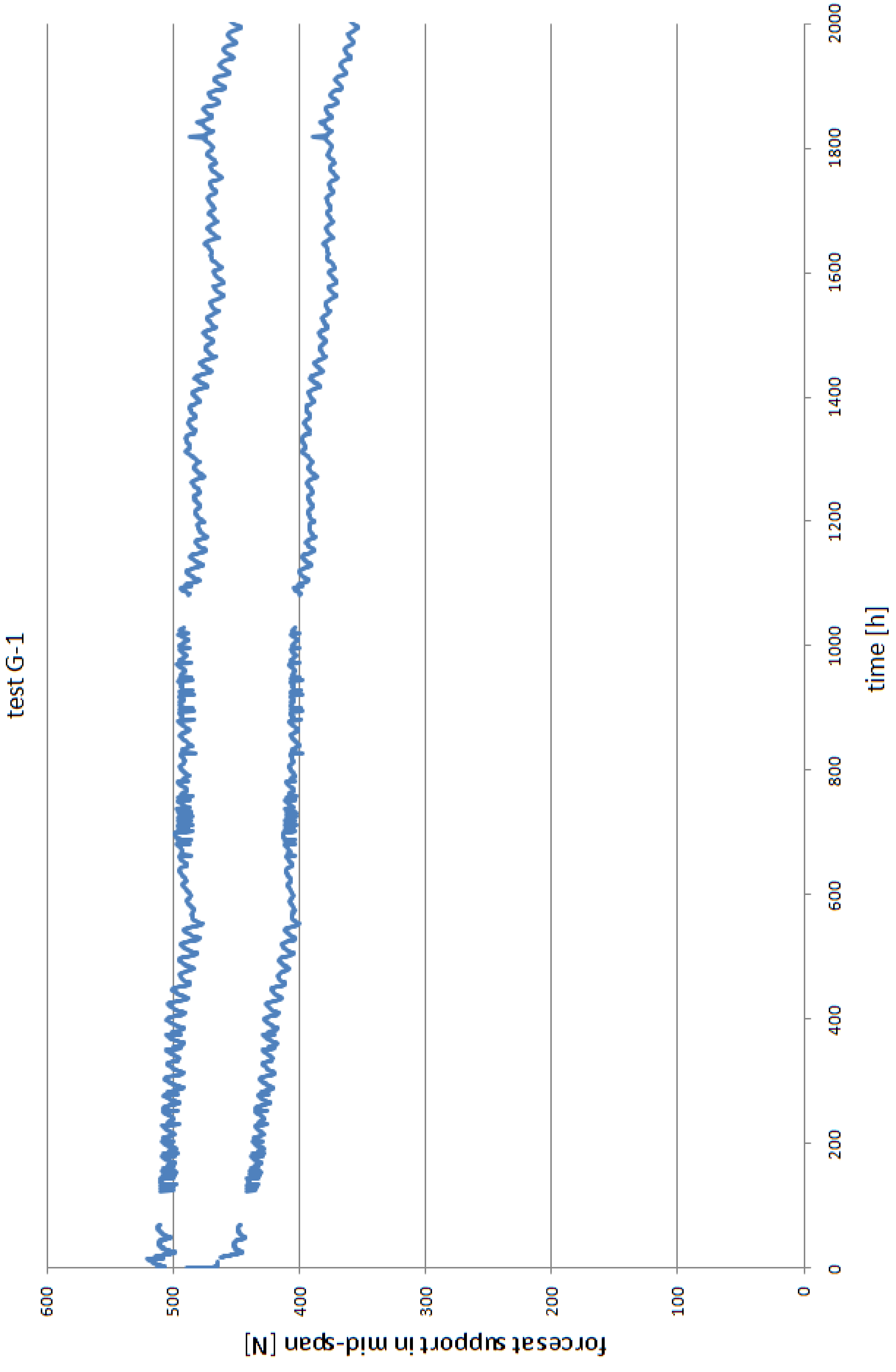
type of panel:	G
application of axial load	centric
face material:	steel
face thickness:	0,60 / 0,60 mm
core material:	EPS
core thickness:	60 mm

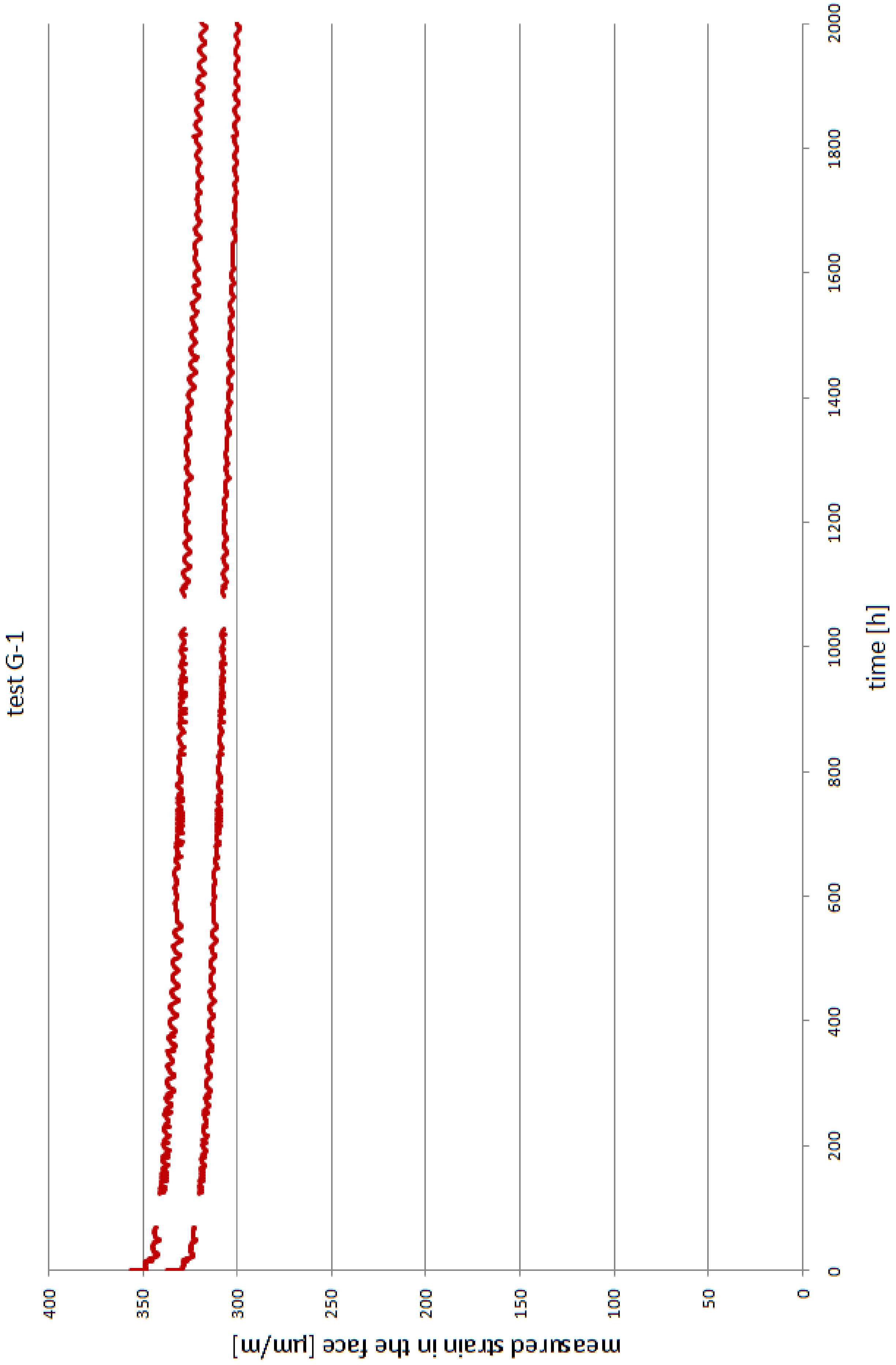
Measured dimensions

width of the panel:	398
thickness of the panel D:	59,6 mm
length L:	3048 mm

Initial deflection at mid-span:	15,5 mm

remarks:


test G-1
time [h]
forcesat support in mid-span [N]
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
100
200
300
400
500
600


test G-1
time [h]
measured strain in the face [µm/m]
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
50
100
150
200
250
300
350
400

No. G-2

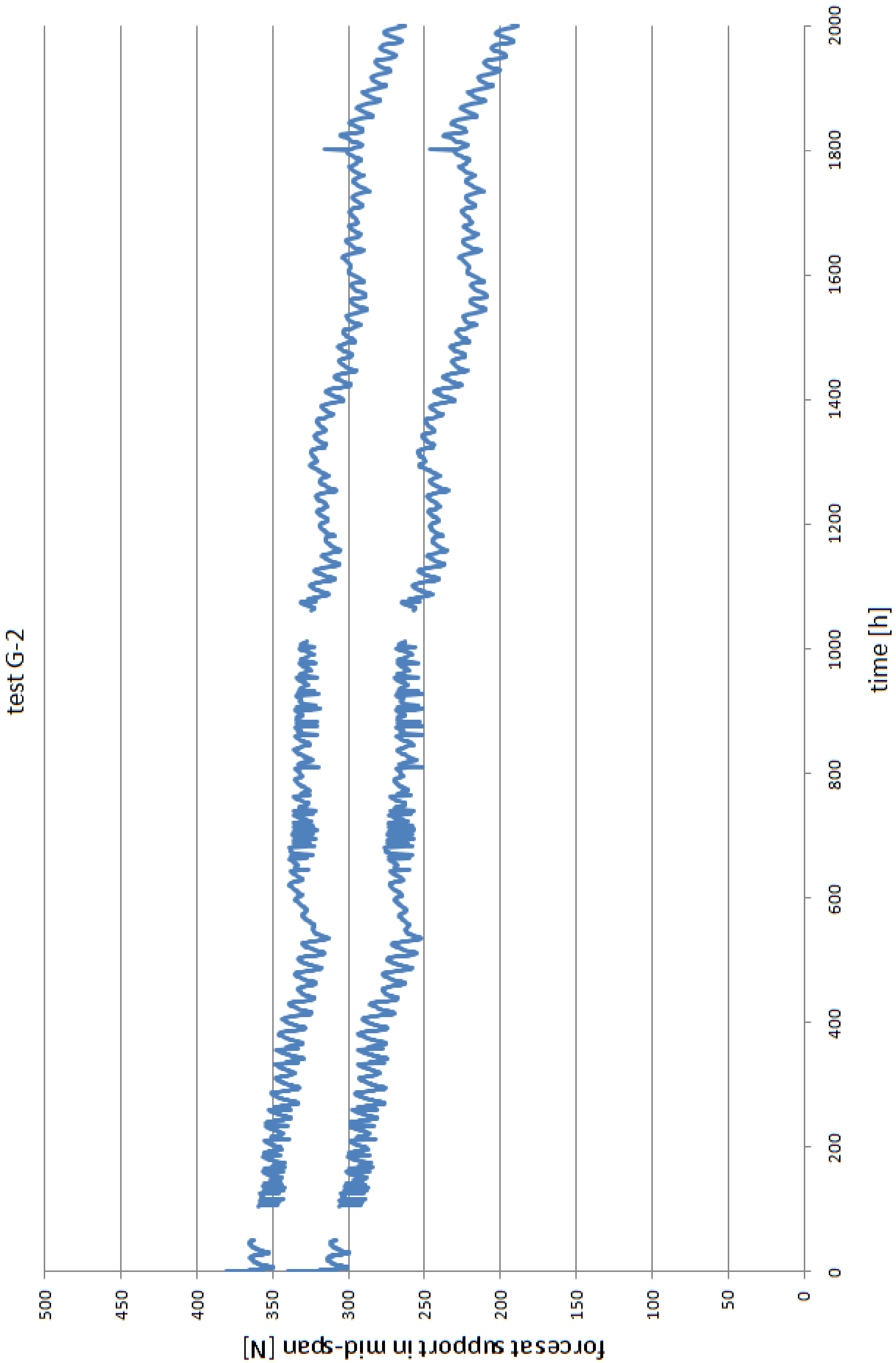
type of panel:	G
application of axial load	eccentric
face material:	steel
face thickness:	0,60 / 0,60 mm
core material:	EPS
core thickness:	60 mm

Measured dimensions

width of the panel:	398 mm
thickness of the panel D:	59,2 mm
length L:	3046 mm

Initial deflection at mid-span:	10,0 mm

remarks: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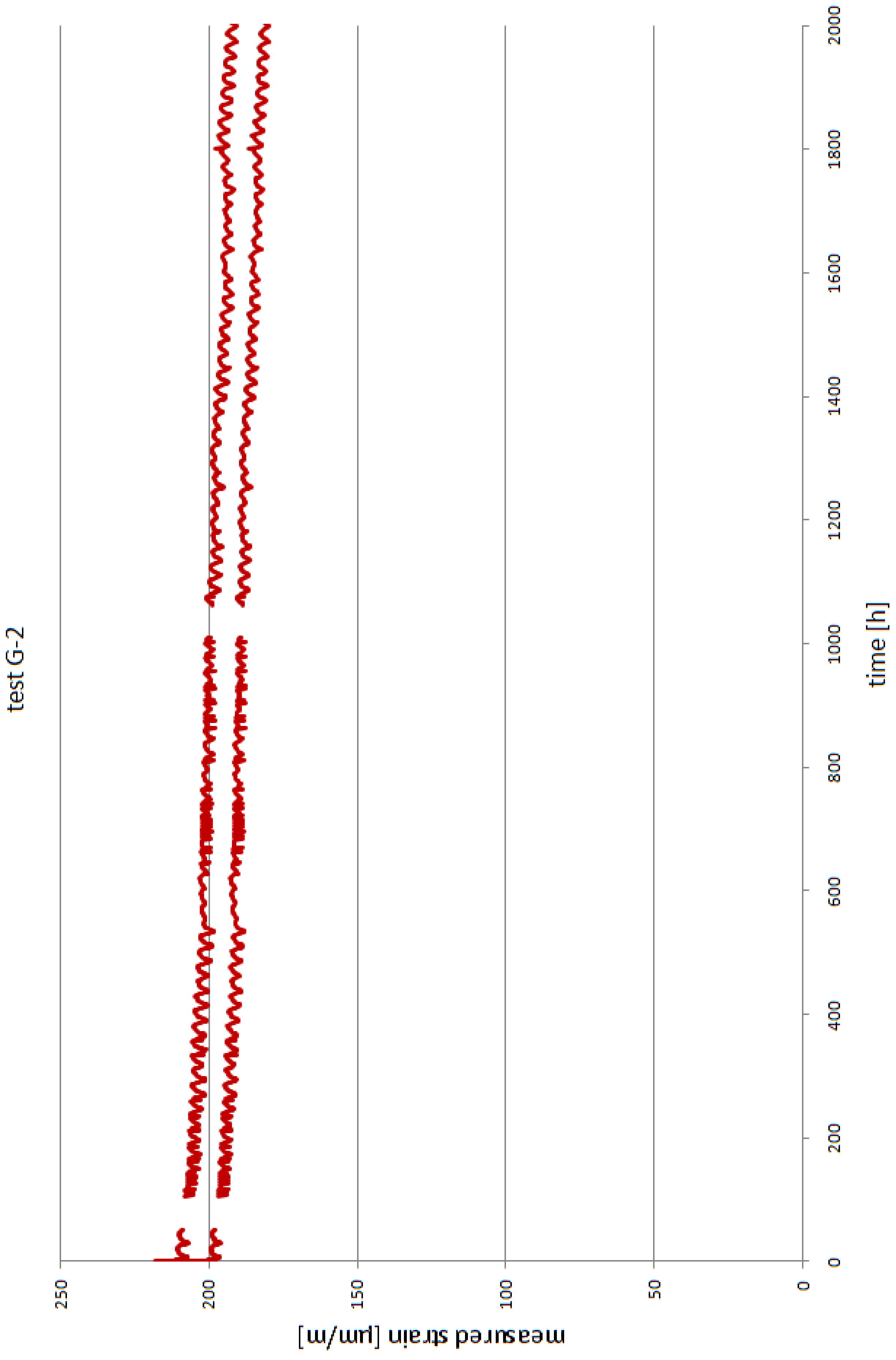
forces at support in mid-span [N]
time [h]
0
50
100
150
200
250
300
350
400
450
500
0
200
400
600
800
1000
1200
1400
1600
1800
2000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measured strain [µm/m]
time [h]
0
50
100
150
200
250
0
200
400
600
800
1000
1200
1400
1600
1800
2000

No. H-1

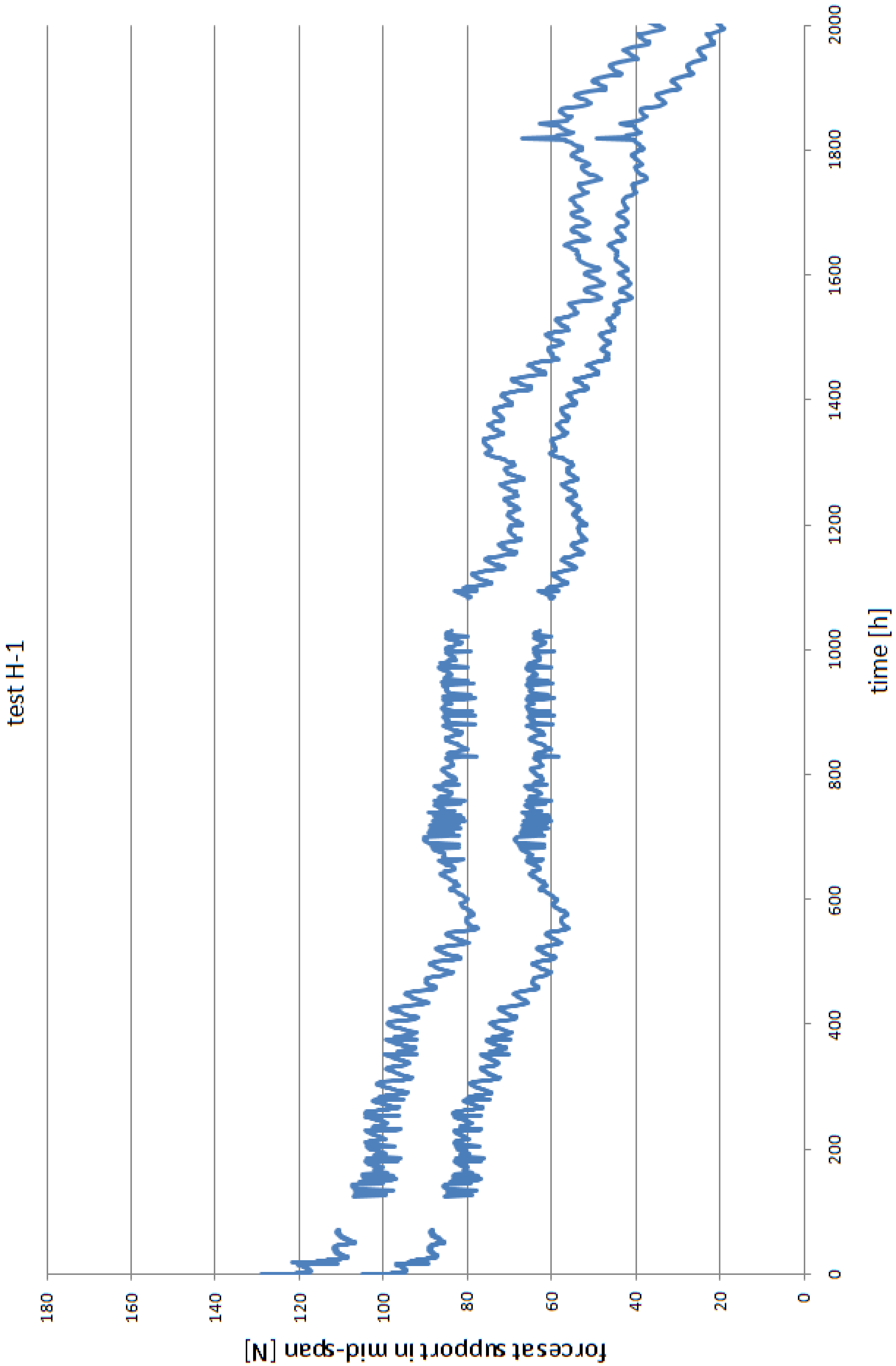
type of panel:	H
application of axial load	centric
face material:	GFRP
face thickness:	1,8 / 1,8 mm
core material:	EPS
core thickness:	60 mm

Measured dimensions

width of the panel:	400 mm
thickness of the panel D:	61,4 mm
length L:	3045 mm

Initial deflection at mid-span: 15,5 mm

remarks: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force at support in mid-span [N]
time [h]
0
20
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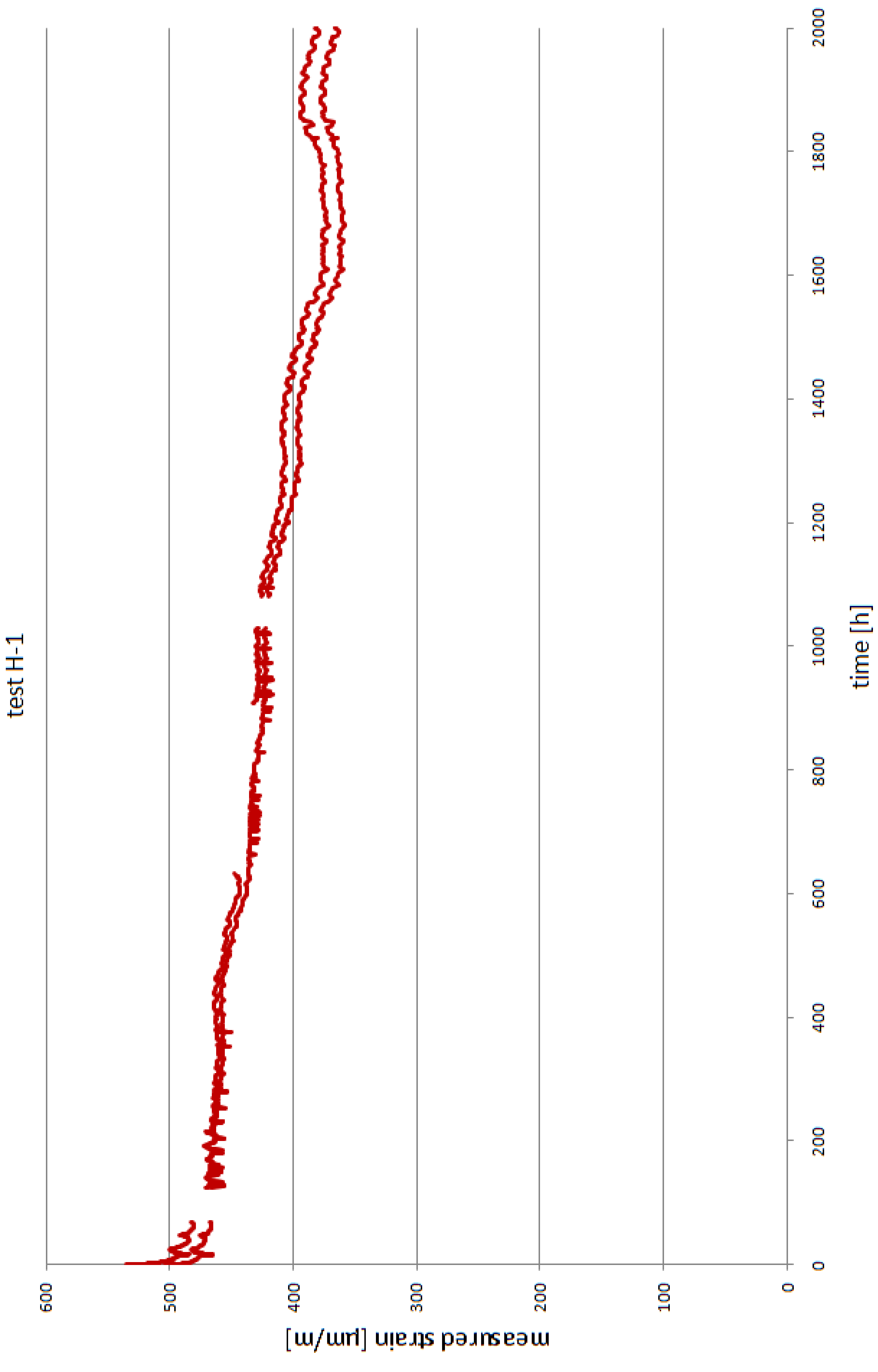
60
80
100
120
140
160
180
0
200
400
600
800
1000
1200
1400
1600
1800
2000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time [h]
measured strain [µm/m]
0
200
400
600
800
1000
1200
1400
1600
1800
2000
100
300
500

No. H-2

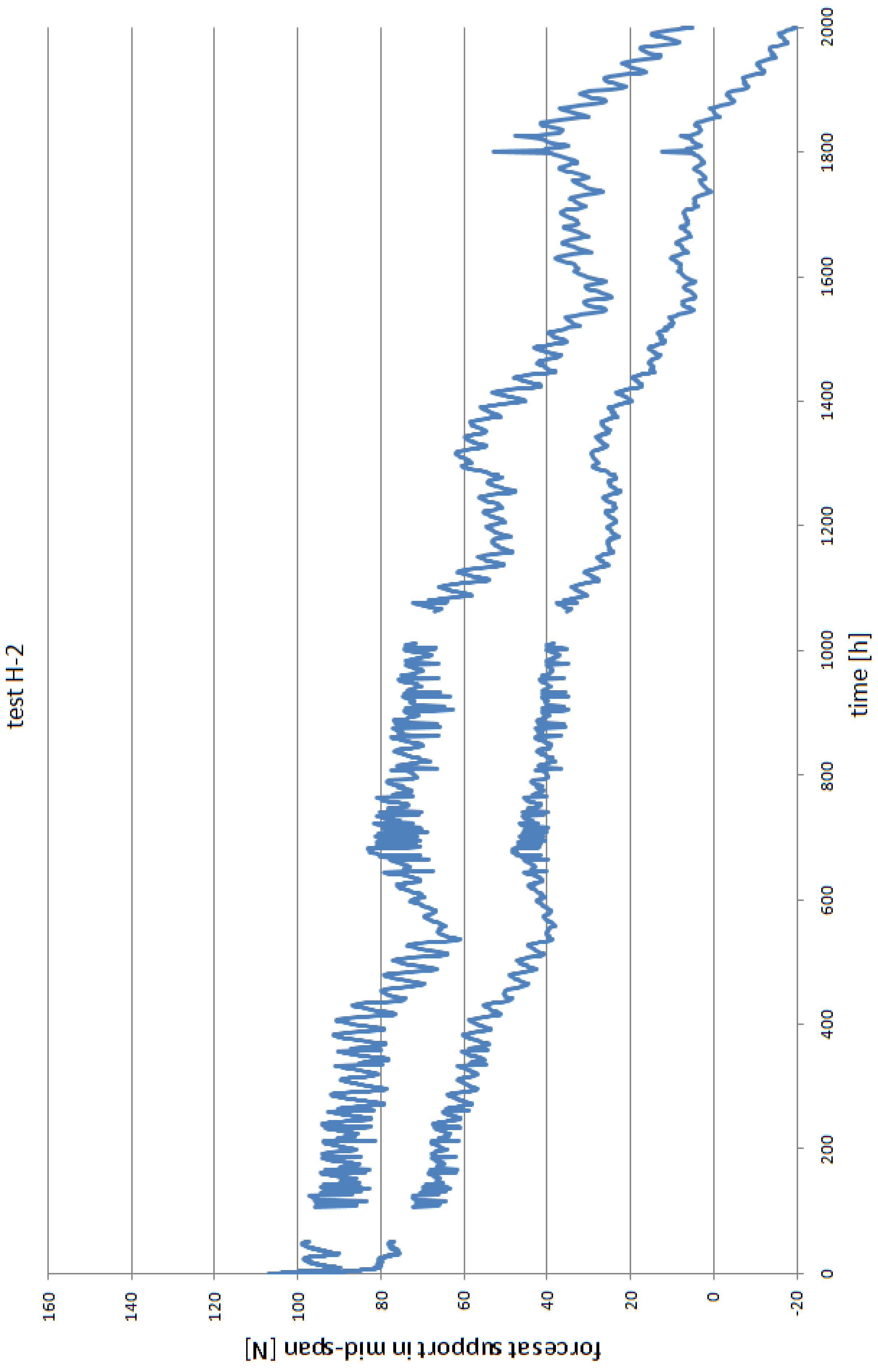
type of panel:	H
application of axial load	eccentric
face material:	GFRP
face thickness:	1,8 / 1,8 mm
core material:	EPS
core thickness:	60 mm

Measured dimensions

width of the panel:	400 mm
thickness of the panel D:	61,2 mm
length L:	3049 mm

Initial deflection at mid-span: 10,5 mm

remarks: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time [h]
force at support in mid-span [N]
0
200
400
600
800
1000
1200
1400
1600
1800
2000
-20
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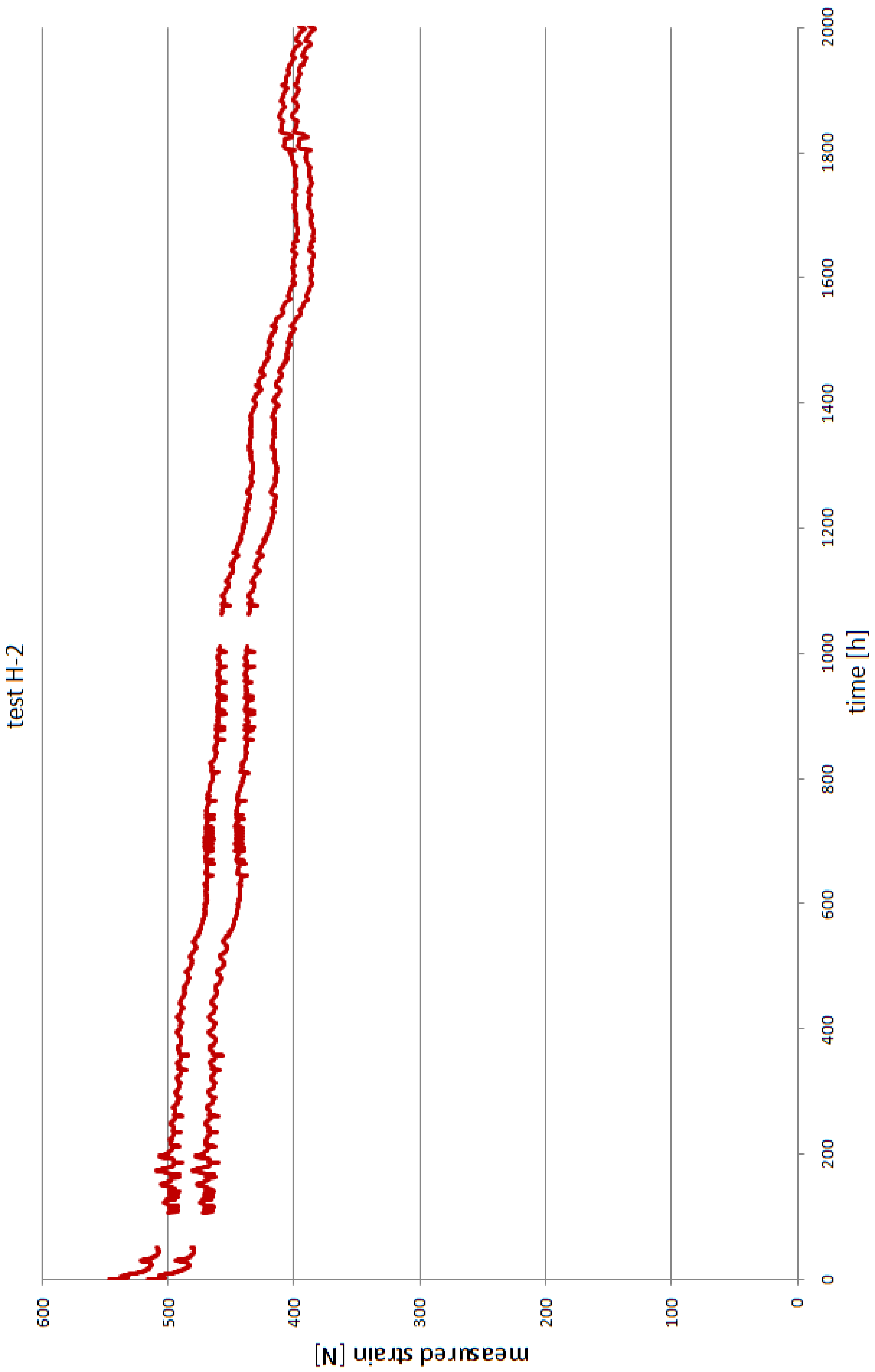
20
40
60
80
100
120
140
160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measured strain [N]
time [h]
0
100
200
300
400
500
600
0
200
400
600
800
1000
1200
1400
1600
1800
2000

No. I-1

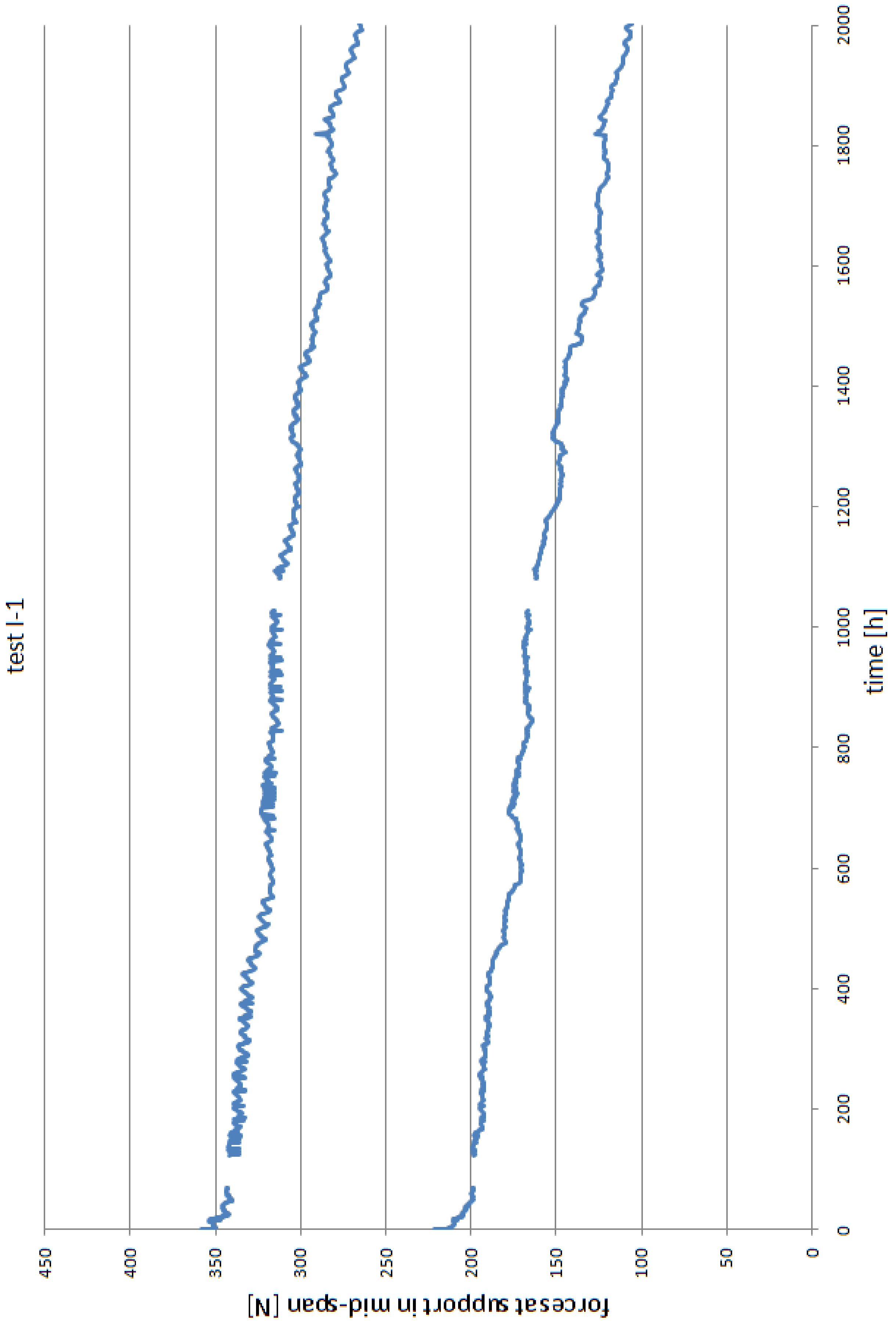
type of panel:	I
application of axial load	centric
face material:	steel
face thickness:	0,60 / 0,60 mm
core material:	mineral wool
core thickness:	60 mm

Measured dimensions

width of the panel:	394 mm
thickness of the panel D:	59,5 mm
length L:	3051 mm

Initial deflection at mid-span:	15,0 mm

remarks:


test I-1
forces at support in mid-span [N]
time [h]
450
400
350
300
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150
100
50
0
0
200
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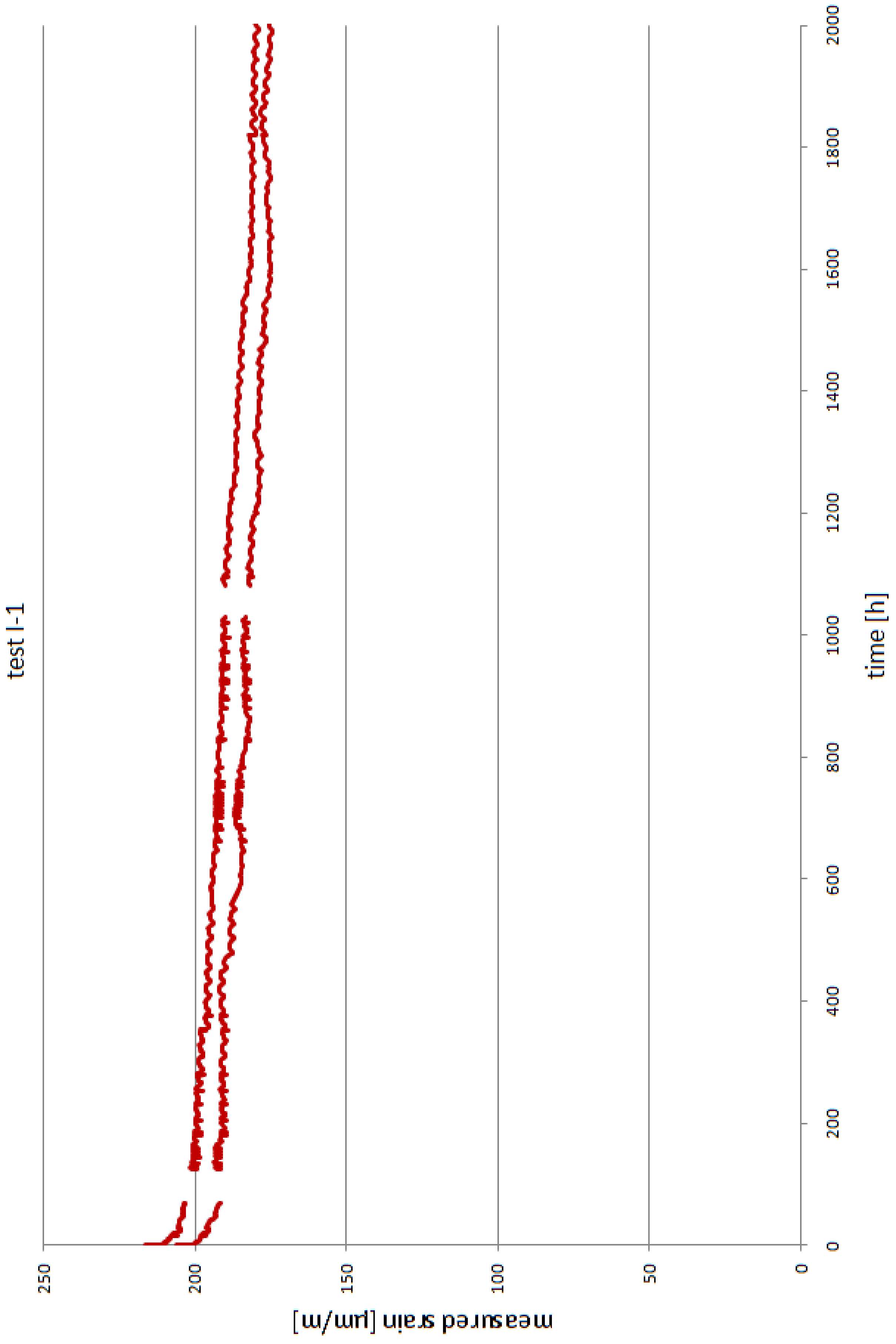
600
800
1000
1200
1400
1600
1800
2000


test I-1
time [h]
measured strain [µm/m]
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
50
100
150
200
250

No. I-2

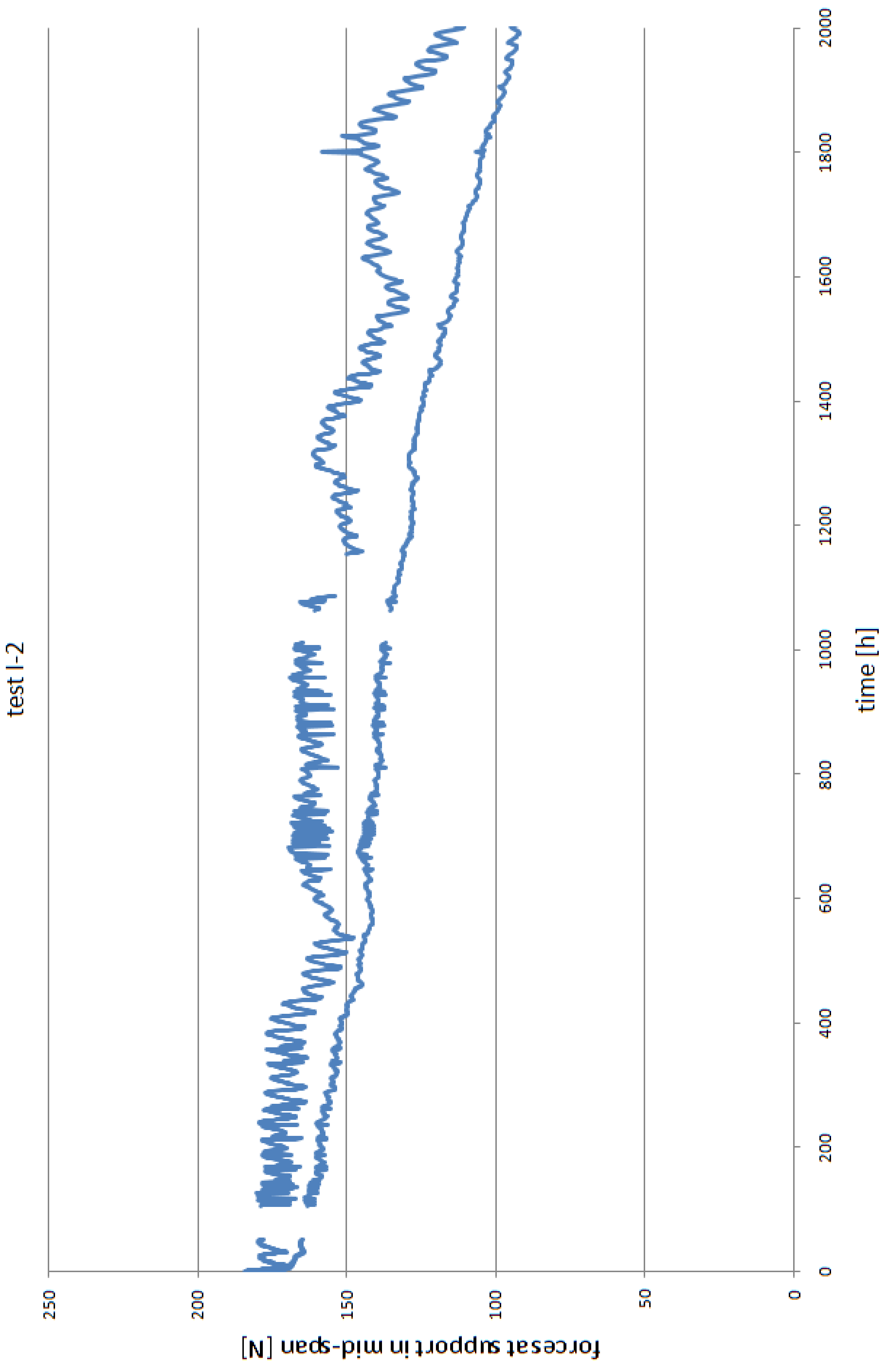
type of panel:	I
application of axial load	eccentric
face material:	steel
face thickness:	0,60 / 0,60 mm
core material:	mineral wool
core thickness:	60 mm

Measured dimensions

width of the panel:	398 mm
thickness of the panel D:	59,4 mm
length L:	3048 mm

Initial deflection at mid-span:	10,0 mm

remarks: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time [h]
force at support in mid-span [N]
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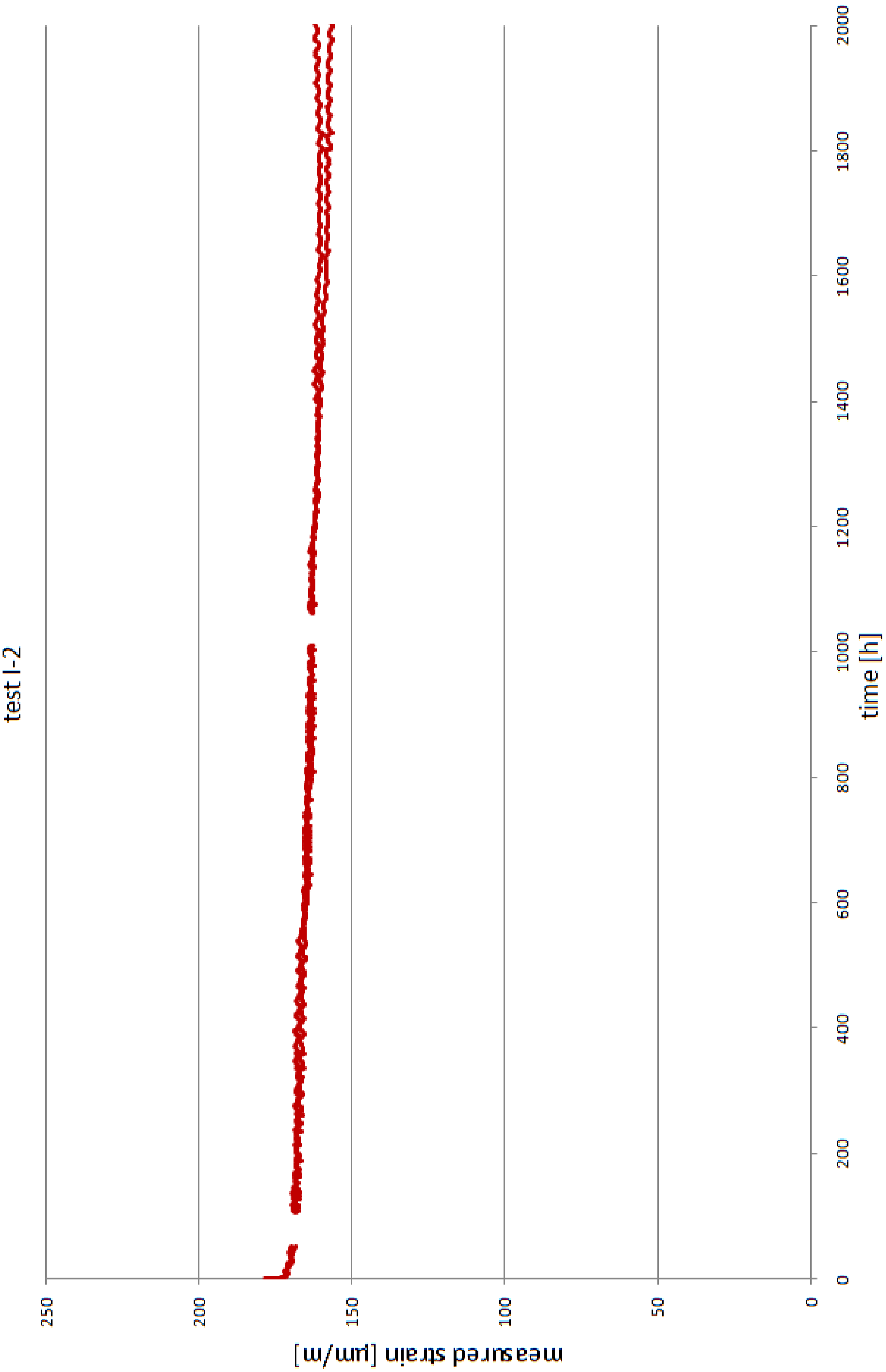
200
400
600
800
1000
1200
1400
1600
1800
2000
0
50
100
150
200
250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measured strain [µm/m]
0
50
100
150
200
250
time [h]
0
200
400
600
800
1000
1200
1400
1600
1800
2000

No. F

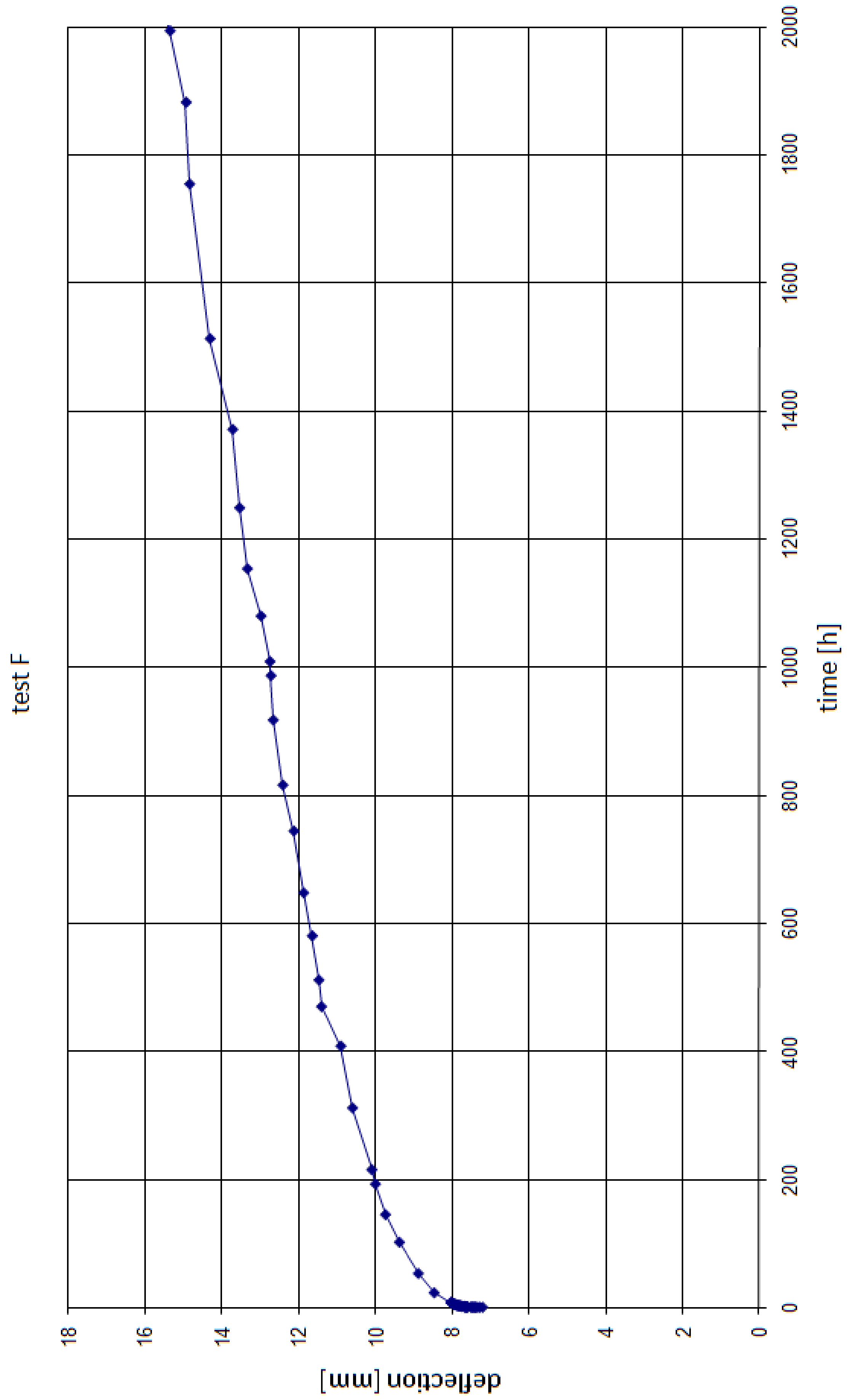
type of panel:	F
face material:	steel
face thickness:	0,75 / 0,75 mm
core material:	PU
core thickness:	60 mm

Measured dimensions

width of the panel:	401 mm
thickness of the panel D:	59,9 mm
length L:	2999 mm

dead load	1,44 kN

remarks:


test F
time [h]
deflection [mm]
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
2
4
6
8
10
12
14
16
18

No. G

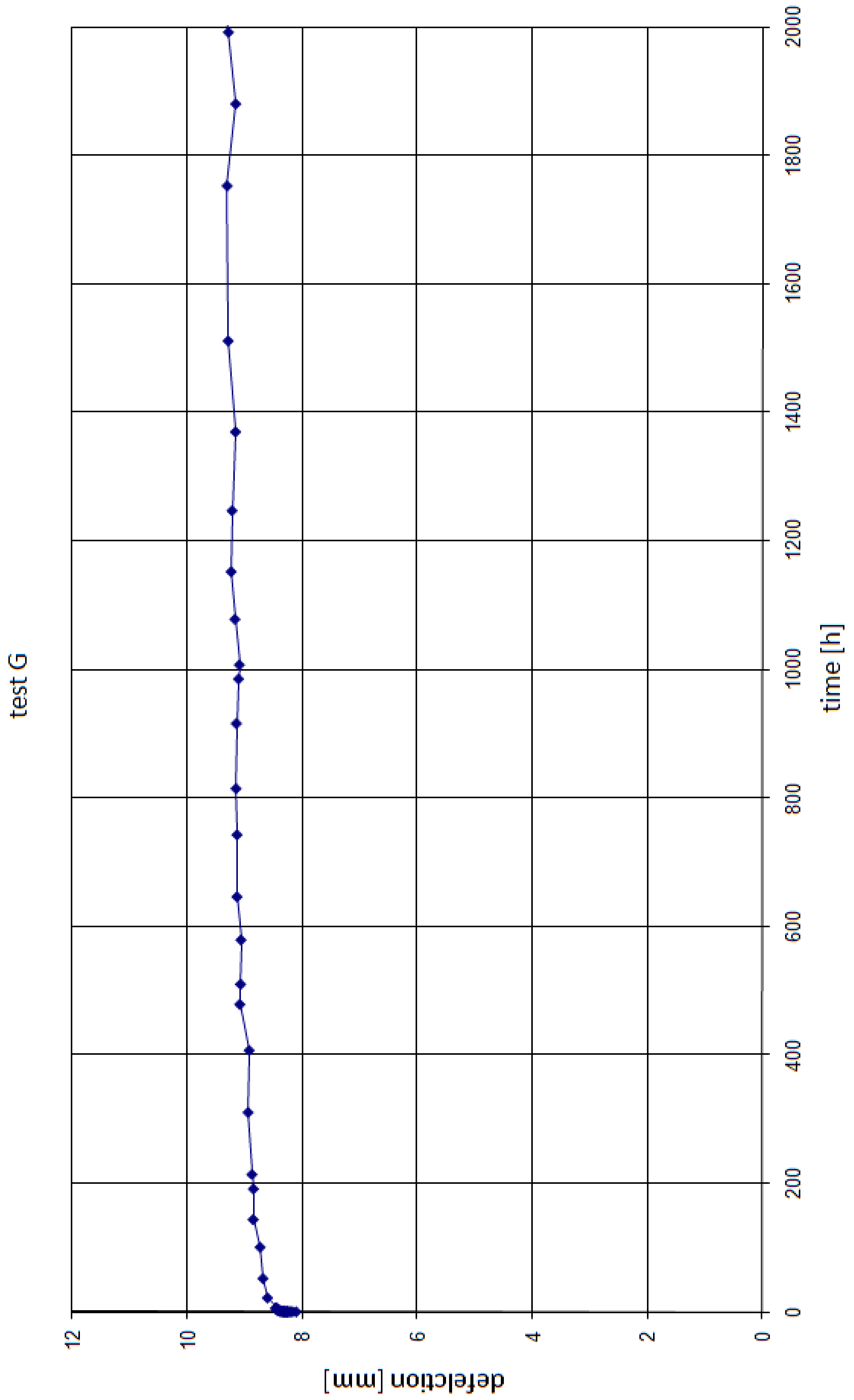
type of panel:	G
face material:	steel
face thickness:	0,60 / 0,60 mm
core material:	EPS
core thickness:	60 mm

Measured dimensions

width of the panel:	399 mm
thickness of the panel D:	59,0 mm
length L:	3000 mm

dead load	1,44 kN

remarks:


test G
time [h]
deflection [mm]
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
2
4
6
8
10
12

No. H

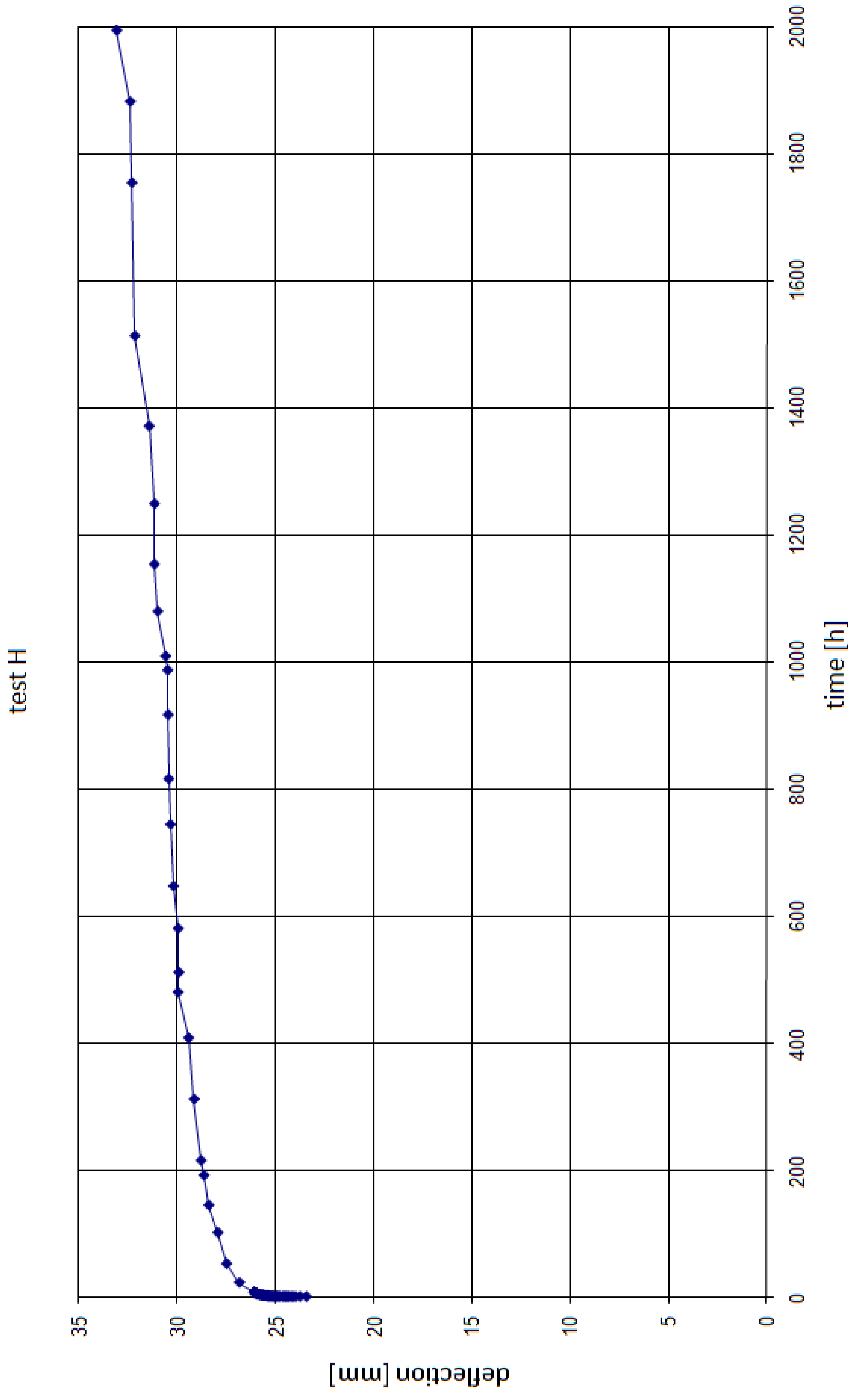
type of panel:	H
face material:	GFRP
face thickness:	1,8 / 1,8 mm
core material:	EPS
core thickness:	60 mm

Measured dimensions

width of the panel:	400 mm
thickness of the panel D:	61,5 mm
length L:	3000 mm

dead load 0,96 kN

remarks:


test H
time [h]
deflection [mm]
0
200
400
600
800
1000
1200
1400
1600
1800
2000
35
30
25
20
15
10
5
0

No. H

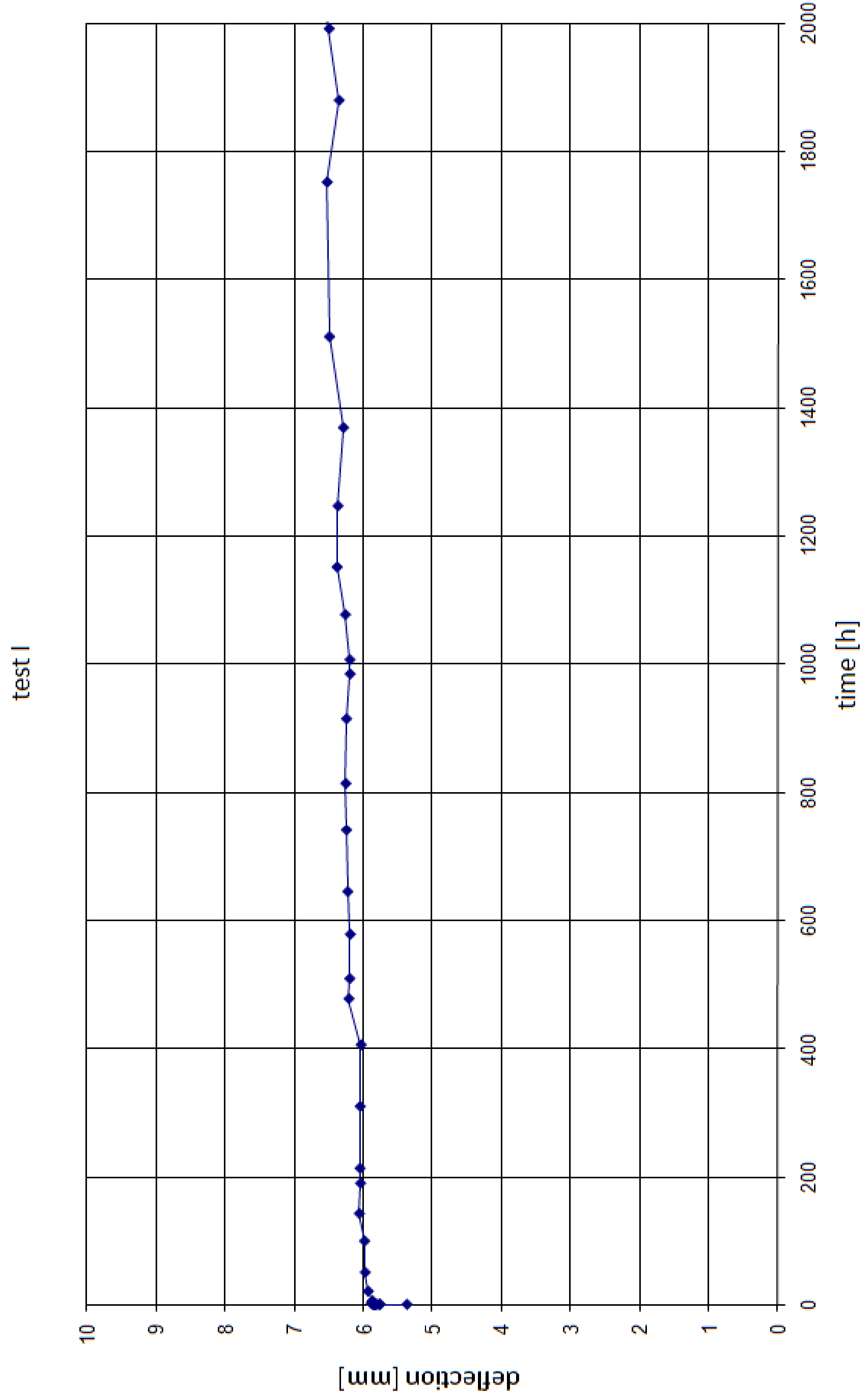
type of panel:	H
face material:	steel
face thickness:	0,60 / 0,60 mm
core material:	mineral wool
core thickness:	60 mm

Measured dimensions

width of the panel:	397 mm
thickness of the panel D:	59,4 mm
length L:	2998 mm

dead load 0,64 kN

remarks:


test I
deflection [mm]
time [h]
0
1
2
3
4
5
6
7
8
9
10
0
200
400
600
800
1000
1200
1400
1600
1800
2000