TECHNICAL UNIVERSITY OF MUNICH

DEPARTMENT AND TEST AUTHORITY FOR ROAD, RAILWAY AND AIRFIELD CONSTRUCTION

Univ. Prof. Dr.-Ing. S. Freudenstein

Report No. 3017 of 08.07.2013

RESEARCH REPORT

Investigations on FFU synthetic wood sleepers of 100 mm and 120 mm height

(Client: SEKISU Chemical GmbH)

Research Report No. 3017
Investigations on FFU synthetic wood sleepers
of 100 mm and 120 mm height

SEKISU Chemical GmbH)

1. GENERAL

On behalf of SEKISU Chemical GmbH, investigations were to be carried out on SEKISUI manufactured FFU synthetic wood sleepers with dimensions of 10 x 26 x 260 cm and 12 x 26 x 260 cm respectively (Eslon Neo Lumber) for use in track construction.
According to the client, strands of glass fibre are stretched and moulded with polyurethane in the manufacturing of the synthetic wood sleepers. The sleepers are cut with millimetre precision once they have cured (see Research Report no. 2466).

Following consultation with the EBA (German Railway Authority) and DB (German Railways) the following investigations were to be carried out on the the synthetic wood sleepers:

1. Behaviour of the sleeper under vertical and horizontal loads in the vibration fatigue test. Support in ballast bed in line with DIN EN 13481-3 (Requirements for fastening systems of wooden sleepers).
2. Static and dynamic testing of synthetic wood sleepers based on DIN EN 13230-2.
3. Extraction tests on sleeper screws according to DIN EN 13481-2.

The client supplied the test authority with synthetic wood sleepers with the dimensions 10 x 26 x 260 cm and 12 x 26 x 260 cm.

2. EXECUTION OF THE TESTS

2.1 Vibration fatigue test according to DIN EN 13146-3 (sleeper height 100 mm)

The test was set up and executed as described in Research Report No. 2466. The loading parameters were: a = 33 °, $P_{o,v}$ = 140 kN, X = 15 mm, f = 3 Hz, 3.0 million load cycles, RT (23°C). Each point of support consisted of the following rail fastening components:

- 1 ribbed plate RPBH28SW11
- 4 sleeper screws with the designation "NZ 5.6 10"
- 4 spring washers Fe 6
- 2 clamps Skl 12
- 2 flat washers Uls 6
- 2 hooked bolts Hs 32-5.6 with nuts
- 1 pad PM08 EVA

The displacement of the rails with respect to the sleeper after 3 million load cycles can be seen in Table 1. Standards DIN EN 13481-3 and 13146-4 define no requirements in this regard. Measurement of the deformation was done with dial gauges according to figure 5 of DIN EN 13146-4 (see attachments 2.1 through 2.6).

Table 1:

Synthetic wood sleeper (h = 100 mm) after fatigue test	**resilient rail head displacement**		**permanent rail head displacement**	
	Support 1	Support 2	Support 1	Support 2
3 million load cycles	1.60 mm	1.60 mm	0.45 mm	0.15 mm
Synthetic wood sleeper (h = 160 mm) after fatigue test (Be-2466)	**resilient rail head displacement**		**permanent rail head displacement**	
	Support 1	Support 2	Support 1	Support 2
3 million load cycles	2.12 mm	1.71 mm	0.42 mm	0.29 mm

Based on the experience to hand, the values shown above are within the permissible range. They indicate comparable or lesser deformation than was observed in Research Report No. 2466.

In addition, both the horizontal and vertical movement of the ribbed plate (outer side) was registered. After 3.0 million load cycles, a maximum resilient sinking of

0.23 mm and a maximum permanent sinking of 0.18 mm was registered at the ribbed plate. The horizontal movement (resilient and permanent) of the ribbed plates was around 0.6 mm on average.

Subsequent visual examination of the underside of the sleeper after removal from the ballast bed revealed only slight pressure marks (see photos, attachment 1)

2.2 Static tests in centre of sleeper (sleeper heights 100 mm and 120 mm)

In order to investigate sleeper behaviour when subjected to bending load, static tests were conducted on the centre of the sleeper in line with DIN EN 13230-2.
A sleeper with 100 mm height was used in the first test and another with 120 mm height was used in the second test.

The test setup can be seen in attachment 2. The support spacing was 1.5 m and load plate width was 100 mm. The initial test load was set to 10 kN. Subsequently the load was increased in increments of 10 kN, with sleeper bending registered on four dial gauges. Attachment 3 shows the values of sleeper bending up to a load of 70 kN, corresponding to a torque of 24.5 kNm. Based on the measured deflection, Young's modulus (E) was determined using the following equation:

$$E = \frac{P \cdot l^3}{48 \cdot I \cdot f}$$

E = Young's modulus N/mm²
l = support spacing 1500 mm
I = Moment of inertia [mm^4]
f = Bending deflection [mm]

Young's modulus for the first synthetic wood sleeper (height 100 mm) under bending load is approx. 9800 N/mm² and for the second sleeper (height 120 mm) is approx. 8800 N/mm² (in Research Report No. 2466 it is approx. 7000 N/mm²). With a load of 70 kN the deflection of the sleeper (height 100 mm) is 23 mm and is therefore three times greater than for the sleeper in

Research Report No. 2466. If the Young's modulus was 7000 N/mm² (see Research Report No. 2466), the deflection would even be four times greater.

With a load of 70 kN the deflection of the sleeper (height 120 mm) is 15 mm. In consultation with the client, the further static and dynamic tests were carried out only with sleepers with a height of 120 mm.

2.3 Fatigue testing in centre of sleeper (sleeper height 120 mm)

In order to investigate the behaviour of the synthetic wood sleeper (height 120 mm) under repeated load, a fatigue test of 2 million load cycles in the centre of the sleeper was conducted in line with DIN EN 13230-4. The test setup is shown in attachment 2. The deflection of the sleeper was recorded during the entire testing procedure in the region of maximum torque. The support spacing during testing was 1.5 m, and the load was applied in accordance with DIN EN 13230-4 via a 100 mm wide hinged support.

The applied load was initially up to 65 kN. The fatigue test was then conducted under the following boundary conditions:

Upper test load P_o = 65 kN
Lower test load P_u = 17 kN
Frequency f = 3 Hz

The above load produced a torque of 23 kNm. This torque corresponds to an axle load of 250 kN and train speed $V \geq 200$ km/h.

No damage to the sleeper could be established during the fatigue test of 2 million load cycles. Attachment 4 shows the deflection before, during and after the fatigue test. It indicates that the resilient deflection after 2 million load cycles is only 0.25 mm greater than at the start of the test. It is also evident from attachment 4 that deformation remained nearly constant throughout the entire fatigue test, i.e. there were no signs of fatigue.

2.4 Fatigue test on the rail seat (sleeper height 120 mm)

The purpose of the fatigue test on the rail seat (compressive load) is to determine how the sleeper behaves under high compression. The fatigue test was conducted on three sleepers (height 120 mm).

The fatigue compression test on the rail seat was conducted in line with DIN EN 13230-2 (concrete sleepers). In compliance with the stated standard, a support spacing of 600 mm was selected. In the first fatigue test, the load was applied via a ribbed plate with the dimensions 160 mm x 370 mm. Since there were no screw holes in the sleeper, the ribbed plate was just set down in the rail seat area and thus not clamped to the sleeper. A load of 150 kN was selected for the fatigue test. This corresponds to an axle load of 250 kN and a train speed V < 200 km/h. A static load of 1.2 x 150 kN = 180 kN was applied before the fatigue test. After the fatigue test the static load was increased to 2 x 150 kN = 300 kN. Attachment 5.1 shows the deflection of sleeper no.1.

The test setup can be seen in attachment 3. The following boundary conditions were chosen:

Upper test load P_o	= 150 kN
Lower test load P_u	= 50 kN
Frequency	= 3 Hz

A sleeper deflection of about 3 mm was recorded at the start of the fatigue test. After 2 million load cycles this increased to about 4 mm, which is roughly twice the figure recorded under the same boundary conditions for the sleeper in test report 2466.

No damage to the sleeper could be established during the fatigue test of 2 million load cycles. The ribbed plate was subsequently removed. Plastic deformations of approximately 0.85 mm (1.0 mm in test report 2466) were detected on the surface of the sleeper's upper side (under the ribbed plate). Aside from this, no other damage could be found.

In consultation with the client, the fatigue test was conducted on the rail seat at two further sleepers (height 120 mm) using ribbed plate Rph 1 with dimensions 160 mm x 345 mm. In addition, a 0.5 mm thick synthetic pad was fitted underneath the ribbed plate. The first sleeper was subjected to 5 million load cycles and the second sleeper to 2 million load cycles. The upper test load remained unchanged at P_o = 150 kN while the lower test load P_u was 50 kN.

Attachments 5.2 and 5.3 show the deflection of both sleepers. For a load of 150 kN they show the deflection registered was 4.8 mm (sleeper no. 2, 5 million load cycles) and 4.2 mm (sleeper no. 3, 2 million load cycles). No damage could be detected on the sleepers.

2.5 Extraction tests (sleeper height 120 mm)

In the extraction tests, a centric tensile force is applied to the sleeper screws and measured by an interposed load cell (see photos, attachment 4).

The tests were conducted in line with EN 13481-2 attachment A on 12 sleeper screws Ss 8-140 and synthetic wood sleepers with a height of 120 mm. According to the client, the standard diameter of the holes for screws Ss 8-140 is 19 mm. To investigate the effect of a larger diameter on the extraction force, 8 further holes of 20 mm diameter were drilled by the client with wood and steel drills in sleepers delivered to the testing institute.

The test was subsequently executed. The load was increased gradually until the screw was extracted. The maximum extraction forces are compiled in table 2:

Table 2: Extraction tests on synthetic wood sleepers (height 120 mm)

Sleeper screw Ss 8, hole diameter 19 mm	
Hole No.	**Maximum extraction force [kN]**
1	55.0
2	59.7
3	54.5
4	58.1
Mean value	**56.8**
Sleeper screw Ss 8, Hole diameter 20 mm with steel drill	
1	53.0
2	56.6
3	49.4
4	51.9
Mean value	**52.7**
Sleeper screw Ss 8, Hole diameter 20 mm with wood drill	
1	44.6
2	51.6
3	48.2
4	53.9
Mean value	**49.6**

For the Ss 8-140 sleeper screw, the table shows mean extraction forces of 57 kN (19 mm standard hole diameter) and 51 kN (20 mm hole diameter). Previous extraction tests on wooden sleeper screws showed extraction forces of approx. 35 kN (see Research Report No. 1687 of 30.06.1997).

3. SUMMARY

On behalf of SEKISU Chemical GmbH, investigations were to be carried out on SEKISUI manufactured FFU synthetic wood sleepers with dimensions of 10 x 26 x 260 cm and 12 x 26 x 260 cm respectively (Eslon Neo Lumber) for use in track construction. According to the client, strands of glass fibre are stretched and moulded with polyurethane in the manufacturing of the synthetic wood sleepers. The sleepers are cut with millimetre precision once they have cured.

Following consultation with the EBA (German Railway Authority) and DB (German Railways) the following investigations were carried out:

1. Behaviour of the sleeper under vertical and horizontal loads in the vibration fatigue test. Support in ballast bed in line with DIN EN 13481-3 (Requirements for fastening systems of wooden sleepers).
2. Static and dynamic testing of synthetic wood sleepers based on DIN EN 13230-2.
3. Extraction tests on sleeper screws according to DIN EN 13481-2.

In the repeated loading test (vibration fatigue test) at room temperature (23°C), no significant damage to sleeper (height 100 mm) or fastenings was detected.

In addition, static and dynamic tests were conducted in the centre of the sleeper and on the rail seat. Based on the deformation measured and maximum loading, it is recommended that only synthetic wood sleepers with a height $\geq$ 120 mm are installed in the track for axle loads of 22.5 t (mainline railway) and train speeds V < 200 km/h . With the exception of plastic deformation on the upper side of the sleeper, no damage to the synthetic wood sleepers (height 120 mm) could be detected in four fatigue tests carried out (1 in the centre of the sleeper, 3 on the rail seat).

With mean extraction forces of 57 kN (19 mm hole diameter) and 51 kN (20 mm hole diameter) for sleeper screw Ss 8-140 in combination with the 120 mm high synthetic wood sleeper, a higher value was recorded than in previous tests on wooden sleepers (35 kN).

Munich, 08.07.2013

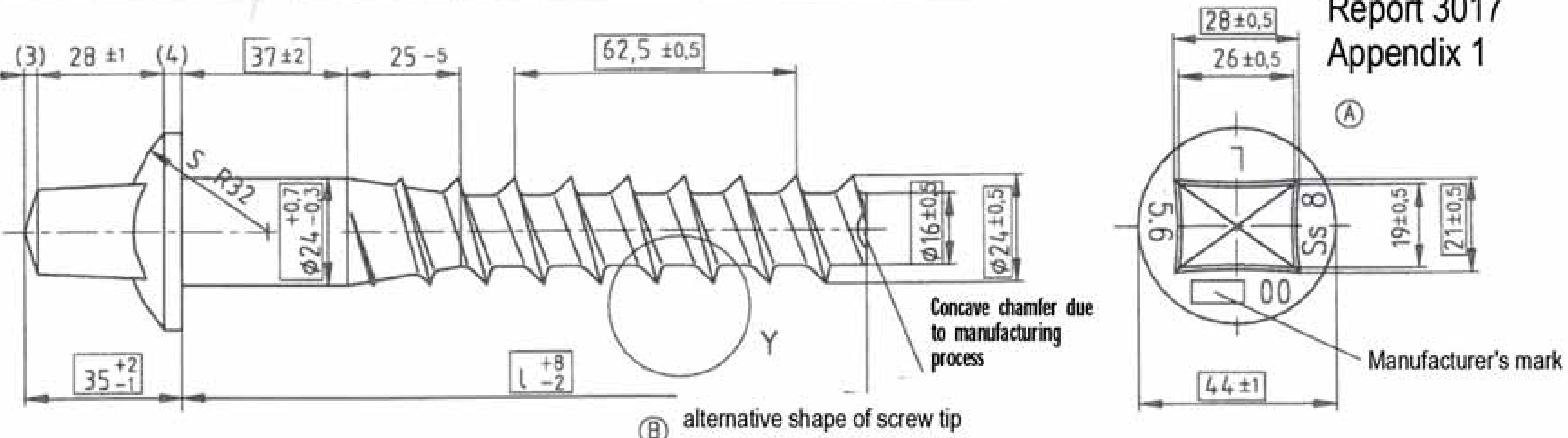
For execution and evaluation of the tests:

BAYERN · TECHNISCHE UNIVERSITÄT MÜNCHEN · PRÜFAMT FÜR VERKEHRSWEGEBAU

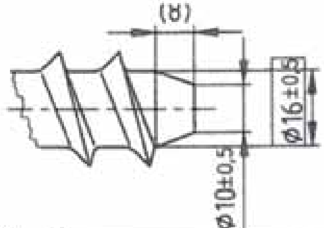
(Dr.-Ing. S. Freudenstein)
Univ.-Prof.

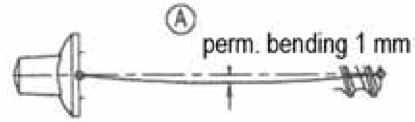
(Dr.-Ing. D. Iliev)

Report 3017
Appendix 1

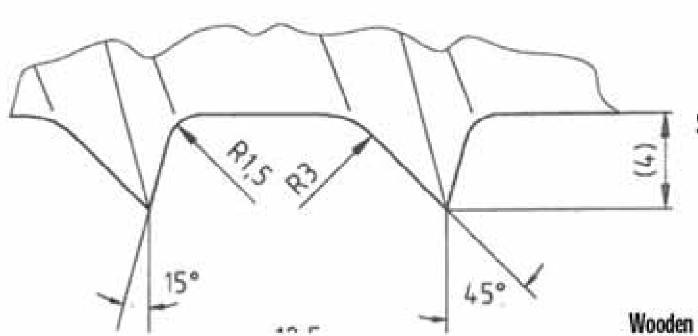


Ⓑ alternative shape of screw tip





Y 5:1



hot galvanised

(9139046294)

Designation (Area of use)	Abbr. designation	L=l+8mm	l (mm)	Weight kg	Material no.
Schwellenschraube	Ss 8-160 fverz	160	152	0,576	491 287
Schwellenschraube	Ss 8-150 fverz	150	142	0,555	491 286
Schwellenschraube	Ss 8-140 fverz	140	132	0,534	491 285
Schwellenschraube	Ss 8-160	160	152	0,568	491 284
Schwellenschraube	Ss 8-150	150	142	0,548	491 283
Schwellenschraube	Ss 8-140	140	132	0,528	491 282

Sleeper screw

Ss 8-140: Holzschwellen Gr.2,4,5;
Ss 8-150: Holzschwellen Gr.1;
Ss 8-160: Brückenbalken

Wooden sleepers
Bridge timbers

EBA
Allgemeine Zulassung
AZ: ./. Datum: ./.
Freigabe als Regelbauart
AZ: BZA Datum: ./.

Deutsche Bahn AG
DB Systemtechnik
Oberbautechnik-T.TZF 61

log 40.1000

Ausgabe	01	02	03	04	05
Datum	08/04	03/06	07/06	05/07	06/08

Zul. Abw.
DIN ISO 2768-c
(Oberfl.)

Maßstab 1:1 5:1
Gewicht
Werkstoff 5.6
Material-Nr.

CAD-Zeichnung
Nicht von Hand ändern

	Datum	Name
Bear.	05.07.04	Weinmann
Gepr.	27.09.04	Danneberg
Norm		

Sleeper screw Ss 8

Zust	Änderung	Datum	Name
D	Werkstoff 5.6	19.06.08	Weinm.
C	L = l + 8 mm	31.05.07	Weinm.
B	altern. Schraubenspitze	07.07.06	Weinm.
A	Bea.-Zul. Durchb.-Kennz.	02.03.06	Weinm.

Deutsche Bahn AG
DB Systemtechnik
(Urspr.)

(Ers. f.:) lotksch 4c (Ers. d.:)

Blatt
Bl.

Notes:

Ⓐ Abbreviated designation, manufacturer's mark, strength class, length of screw and year of manufacture 00 in letter size min. 4 mm, raised 0.5 - 1 mm.

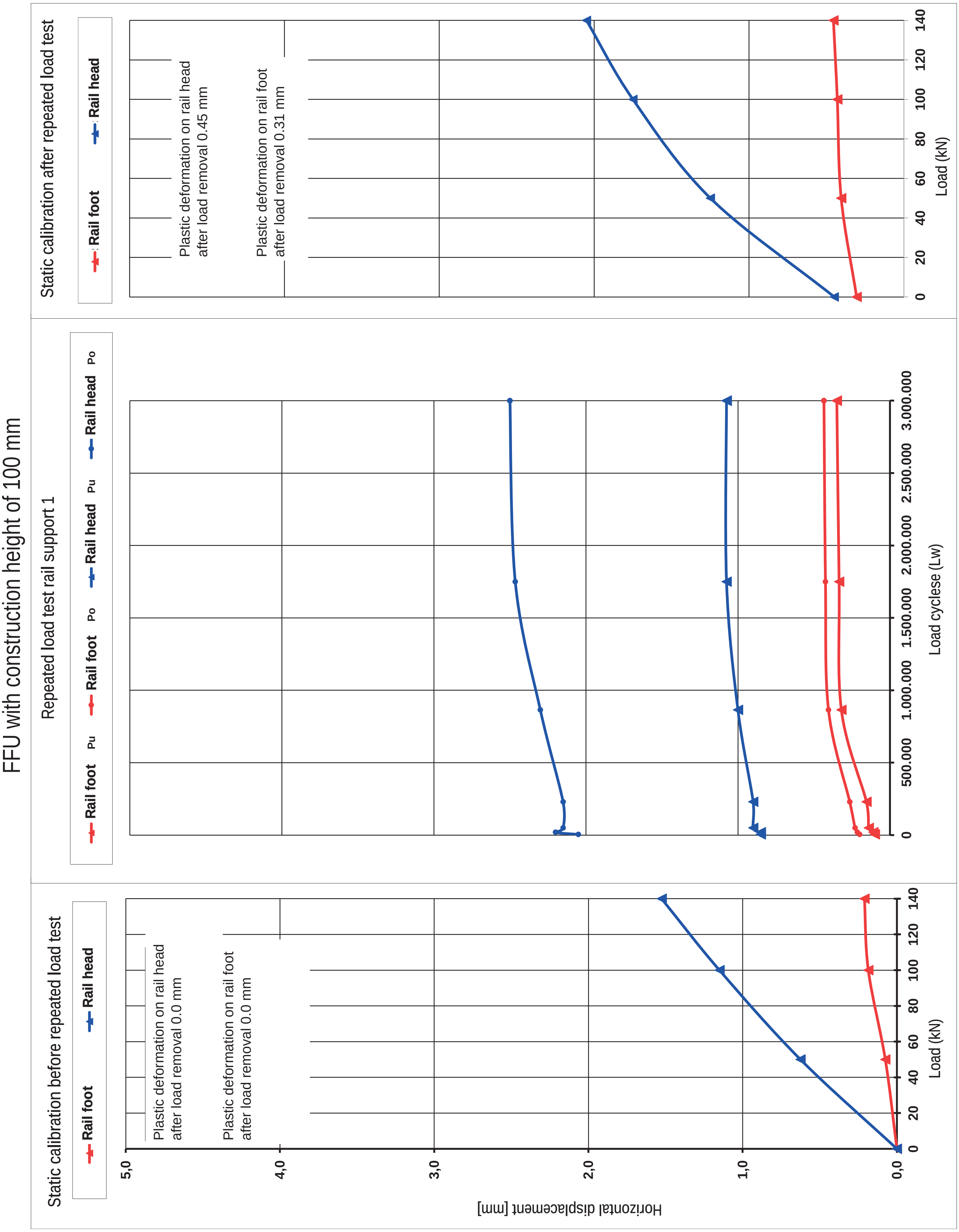
DBS 918 024 applies to production and acceptance.

The end of the thread core can be crater-shaped depending on the manufacturing process.

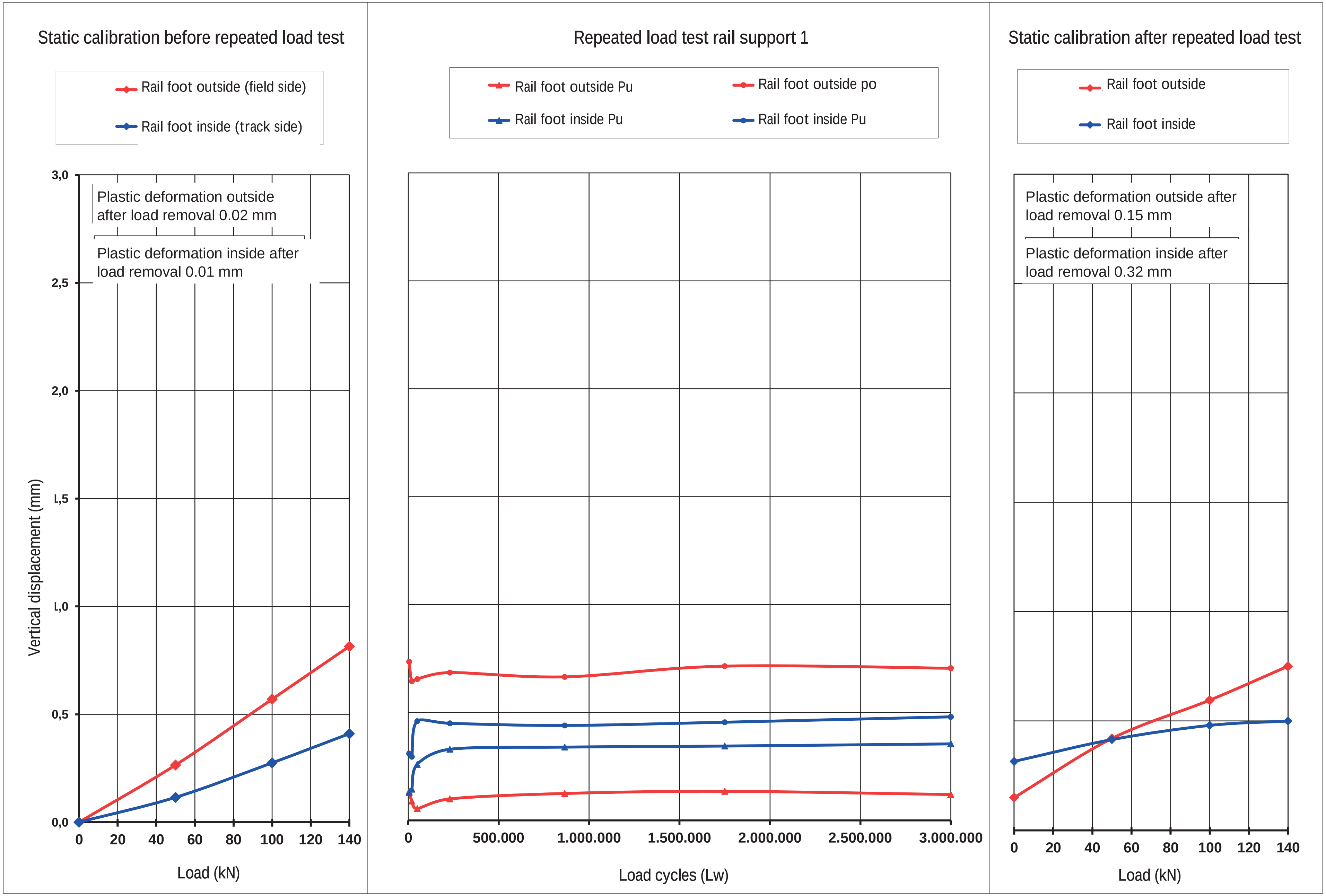
Delivery condition: untreated

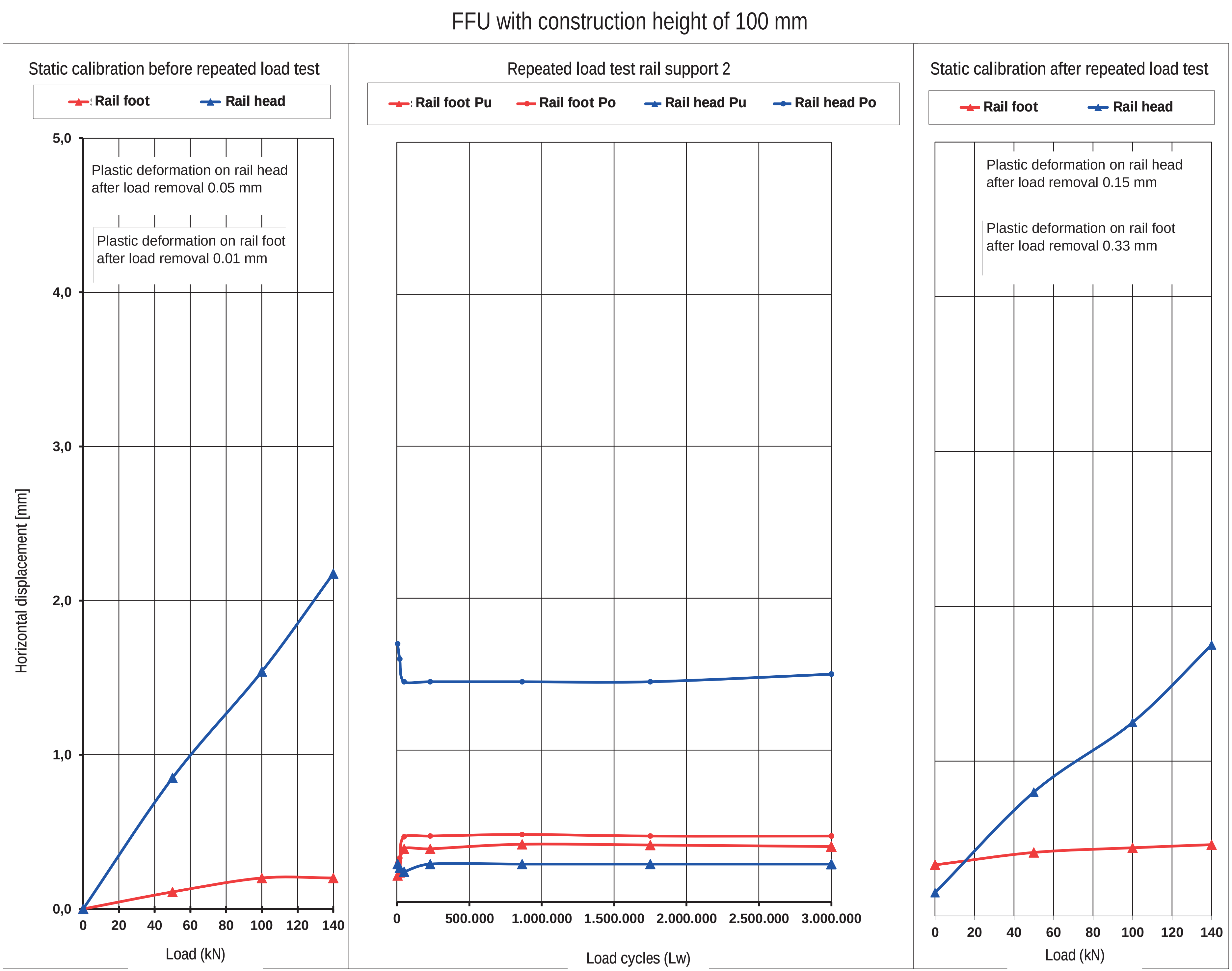
Alternatively hot galvanised according to DIN EN ISO 1461.

The measurements in boxes are to be checked in accordance with the specified test intervals.

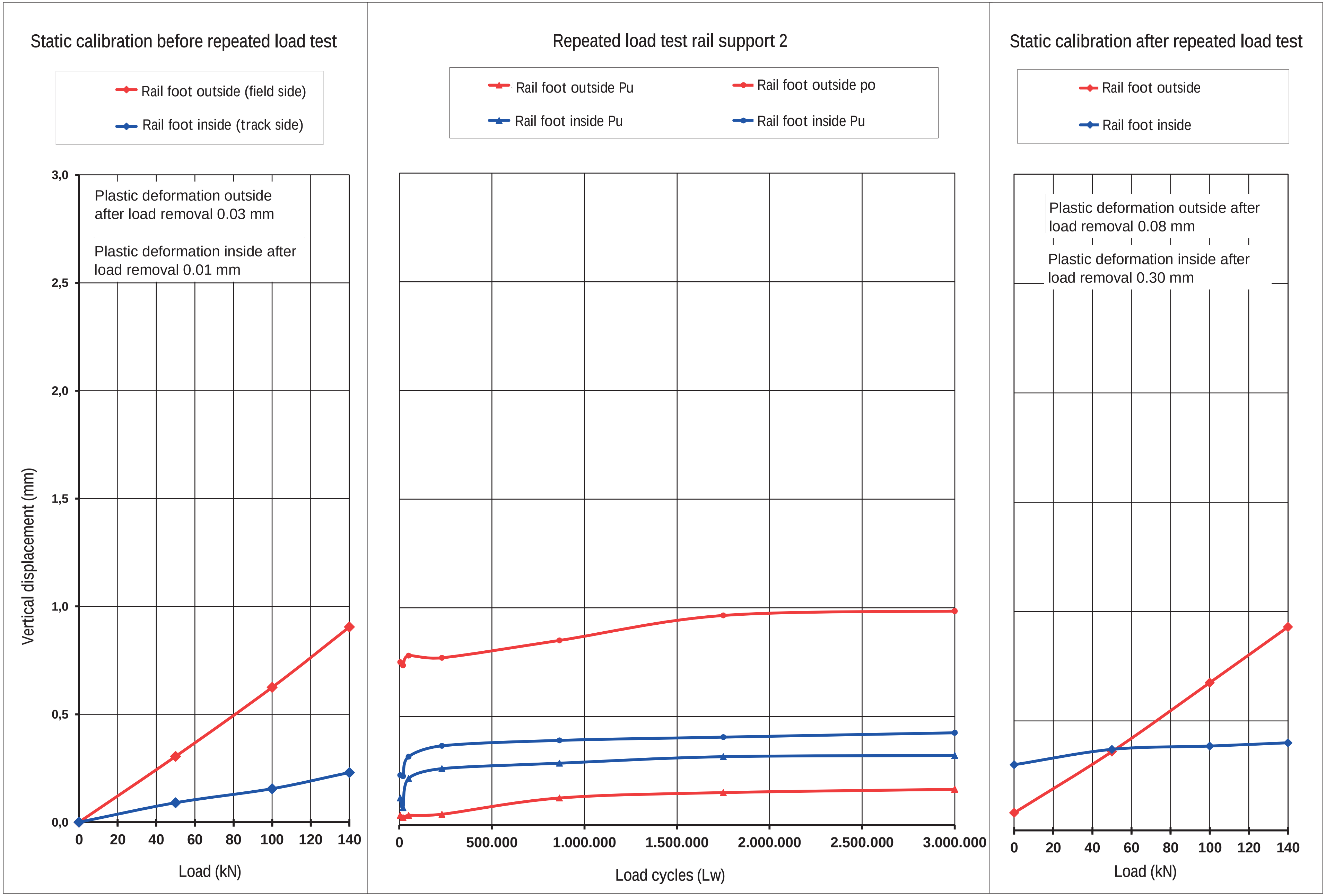

FFU with construction height of 100 mm
Static calibration before repeated load test
Rail foot
Rail head
Plastic deformation on rail head after load removal 0.0 mm
Plastic deformation on rail foot after load removal 0.0 mm
Horizontal displacement [mm]
0,0
1,0
2,0
3,0
4,0
5,0
Load (kN)
0
20
40
60
80
100
120
140
Repeated load test rail support 1
Rail foot Pu
Rail foot Po
Rail head Pu
Rail head Po
Load cyclese (Lw)
0
500.000
1.000.000
1.500.000
2.000.000
2.500.000
3.000.000
Static calibration after repeated load test
Rail foot
Rail head
Plastic deformation on rail head after load removal 0.45 mm
Plastic deformation on rail foot after load removal 0.31 mm
Load (kN)
0
20
40
60
80
100
120
140

FFU with construction height of 100 mm

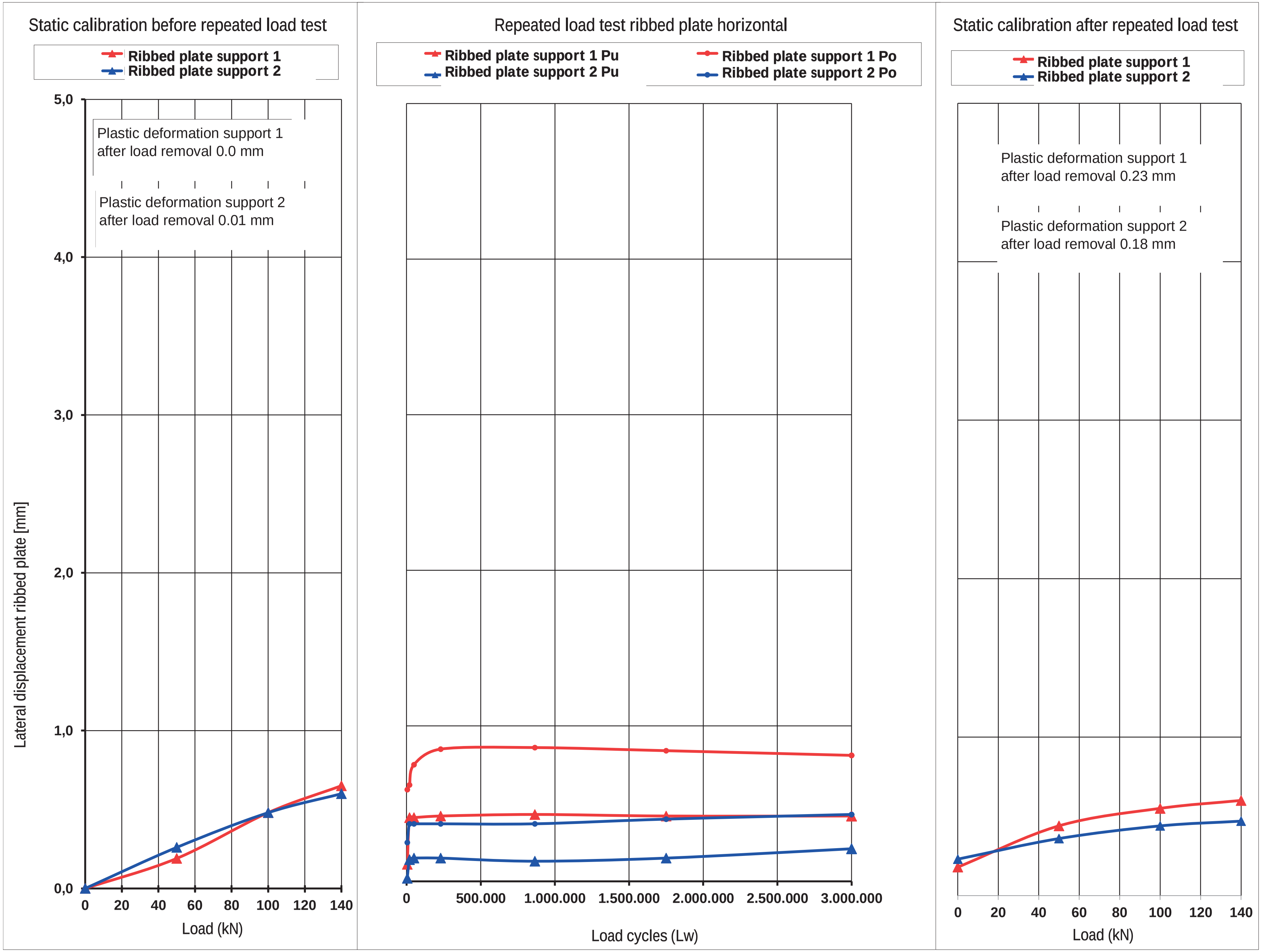



FFU with construction height of 100 mm
Static calibration before repeated load test
Rail foot
Rail head
Plastic deformation on rail head after load removal 0.05 mm
Plastic deformation on rail foot after load removal 0.01 mm
Horizontal displacement [mm]
5,0
4,0
3,0
2,0
1,0
0,0
0
20
40
60
80
100
120
140
Load (kN)
Repeated load test rail support 2
Rail foot Pu
Rail foot Po
Rail head Pu
Rail head Po
0
500.000
1.000.000
1.500.000
2.000.000
2.500.000
3.000.000
Load cycles (Lw)
Static calibration after repeated load test
Rail foot
Rail head
Plastic deformation on rail head after load removal 0.15 mm
Plastic deformation on rail foot after load removal 0.33 mm
0
20
40
60
80
100
120
140
Load (kN)

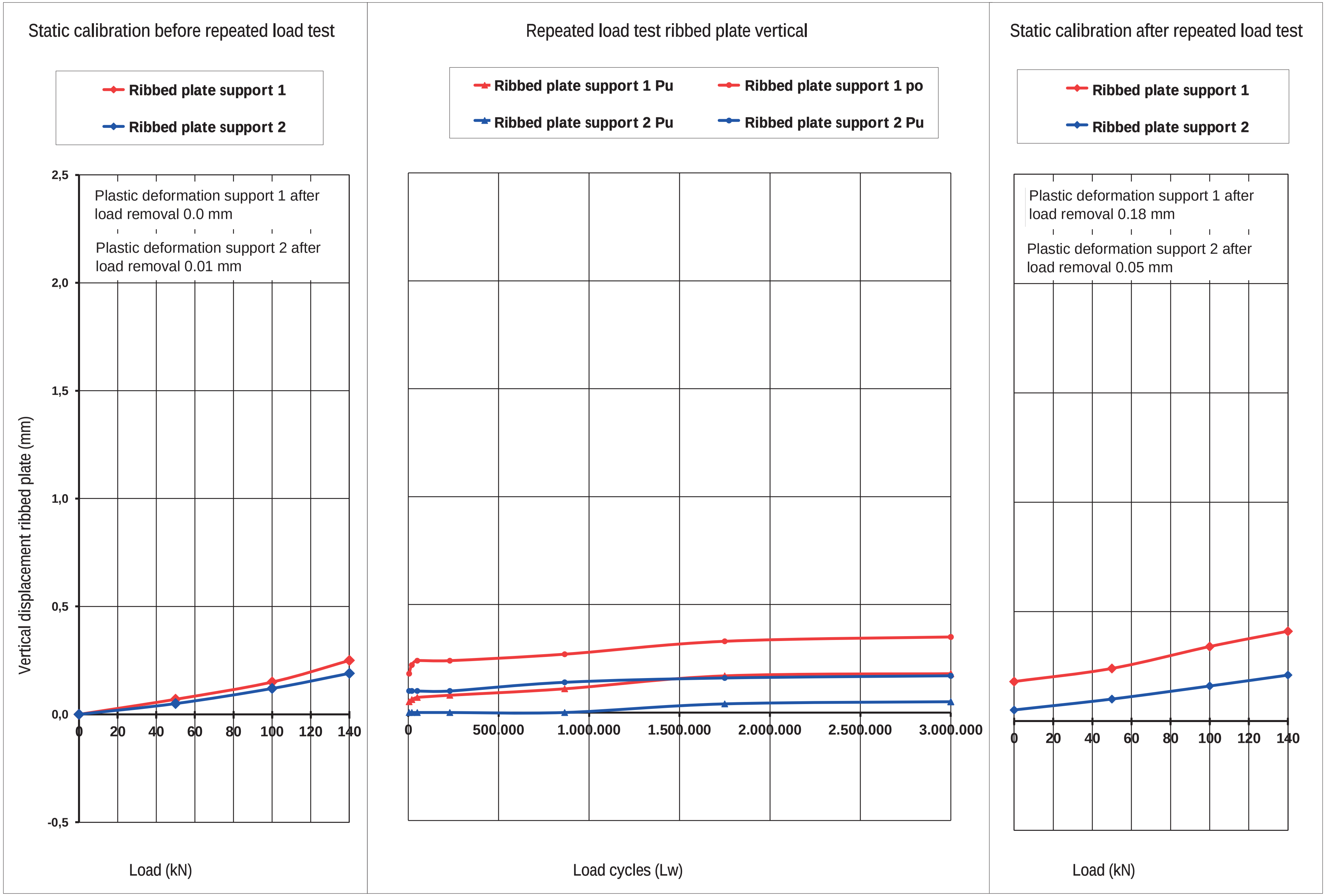
FFU with construction height of 100 mm

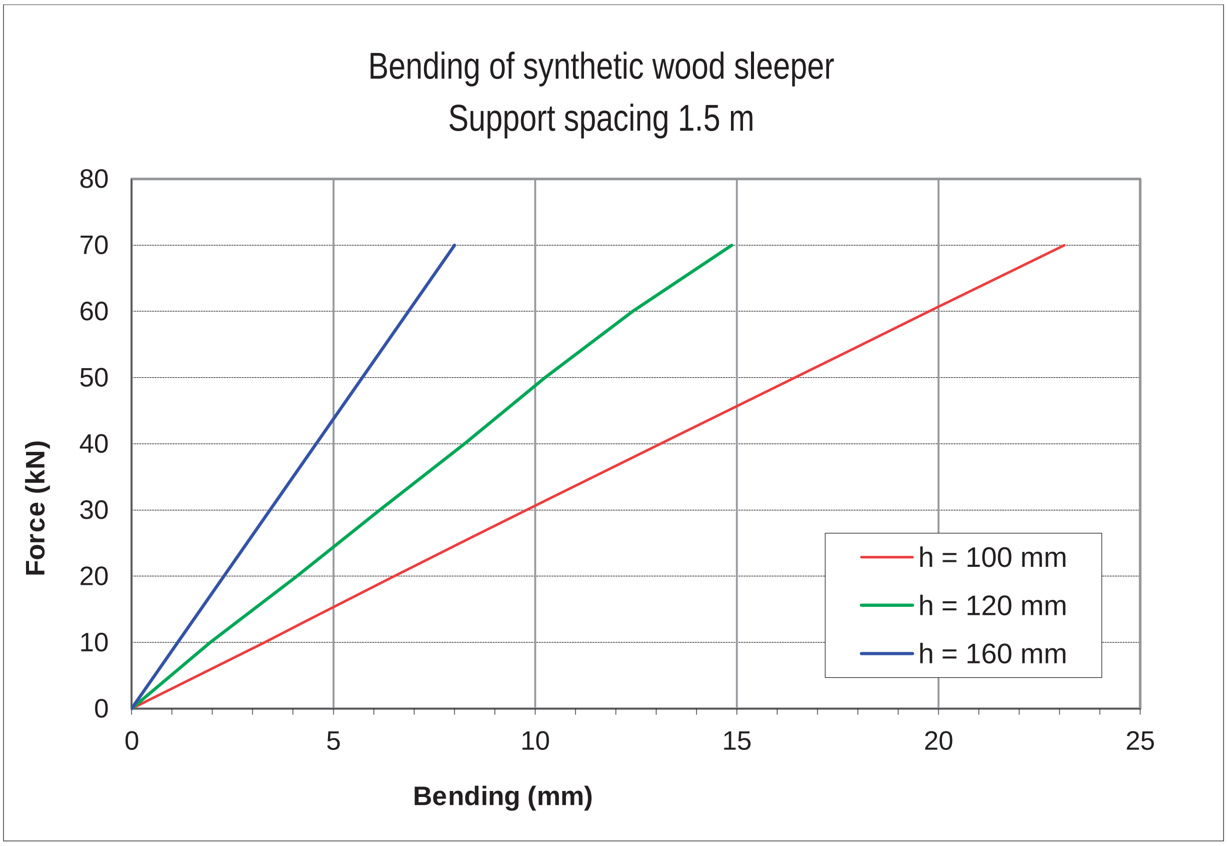


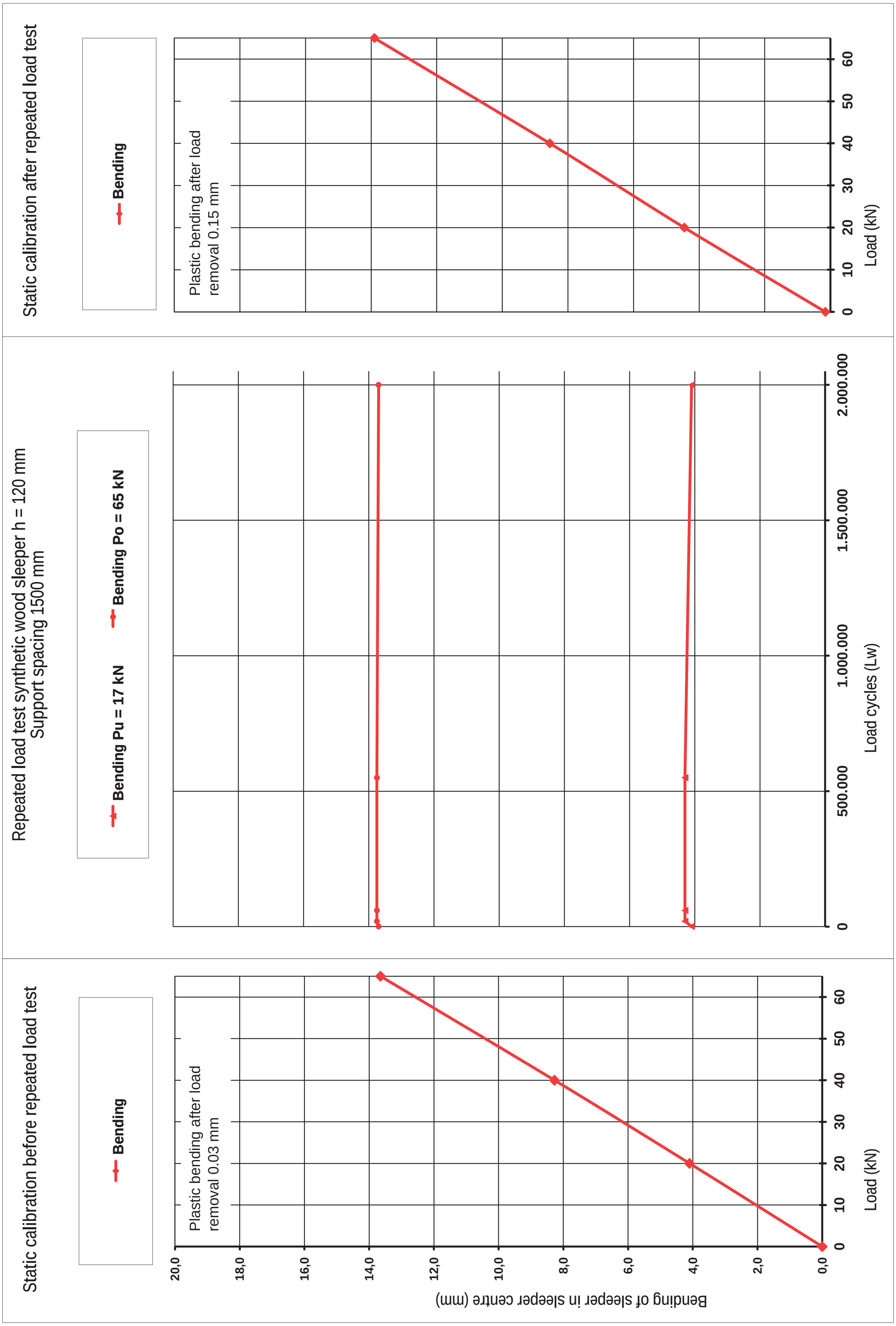
FFU with construction height of 100 mm

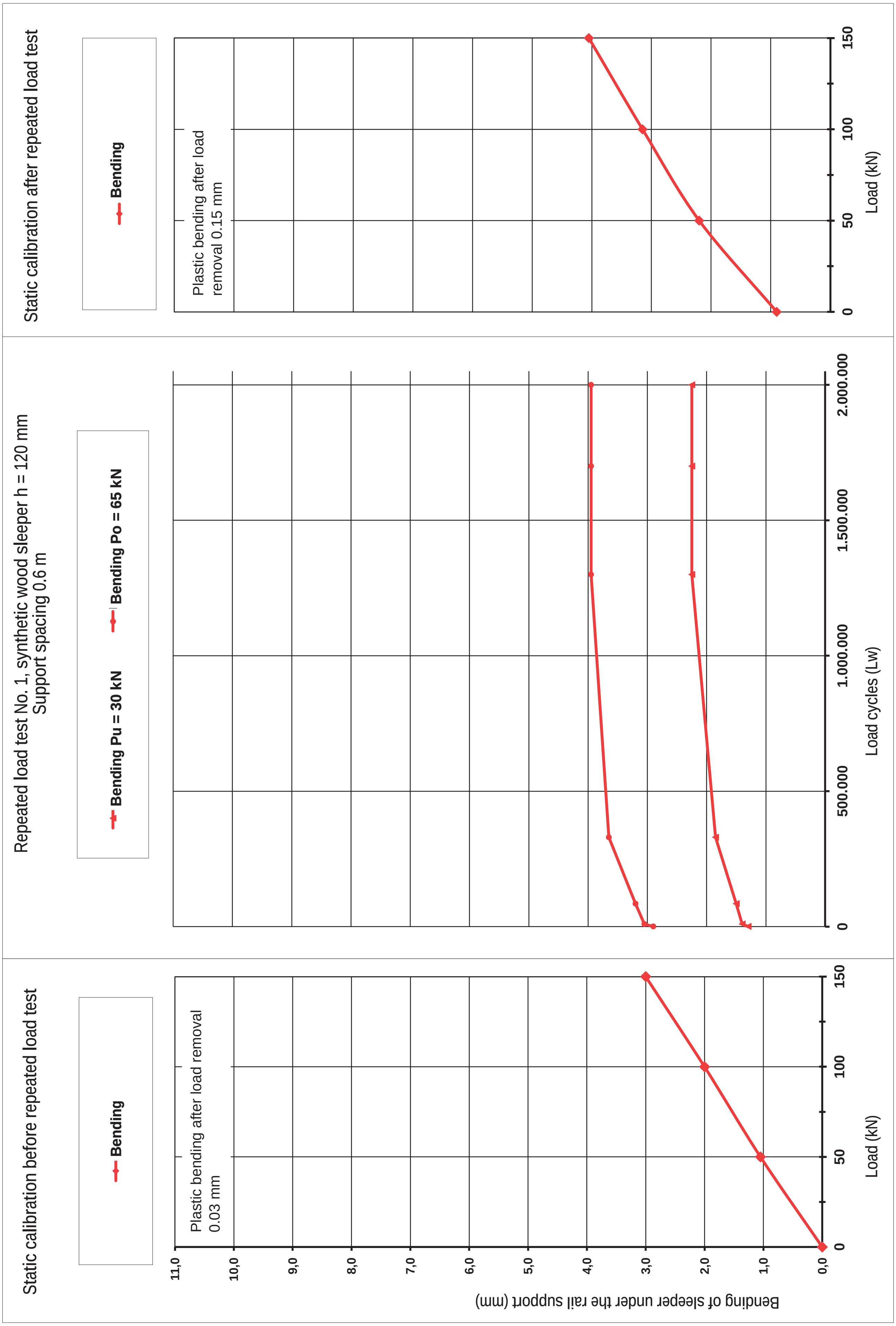


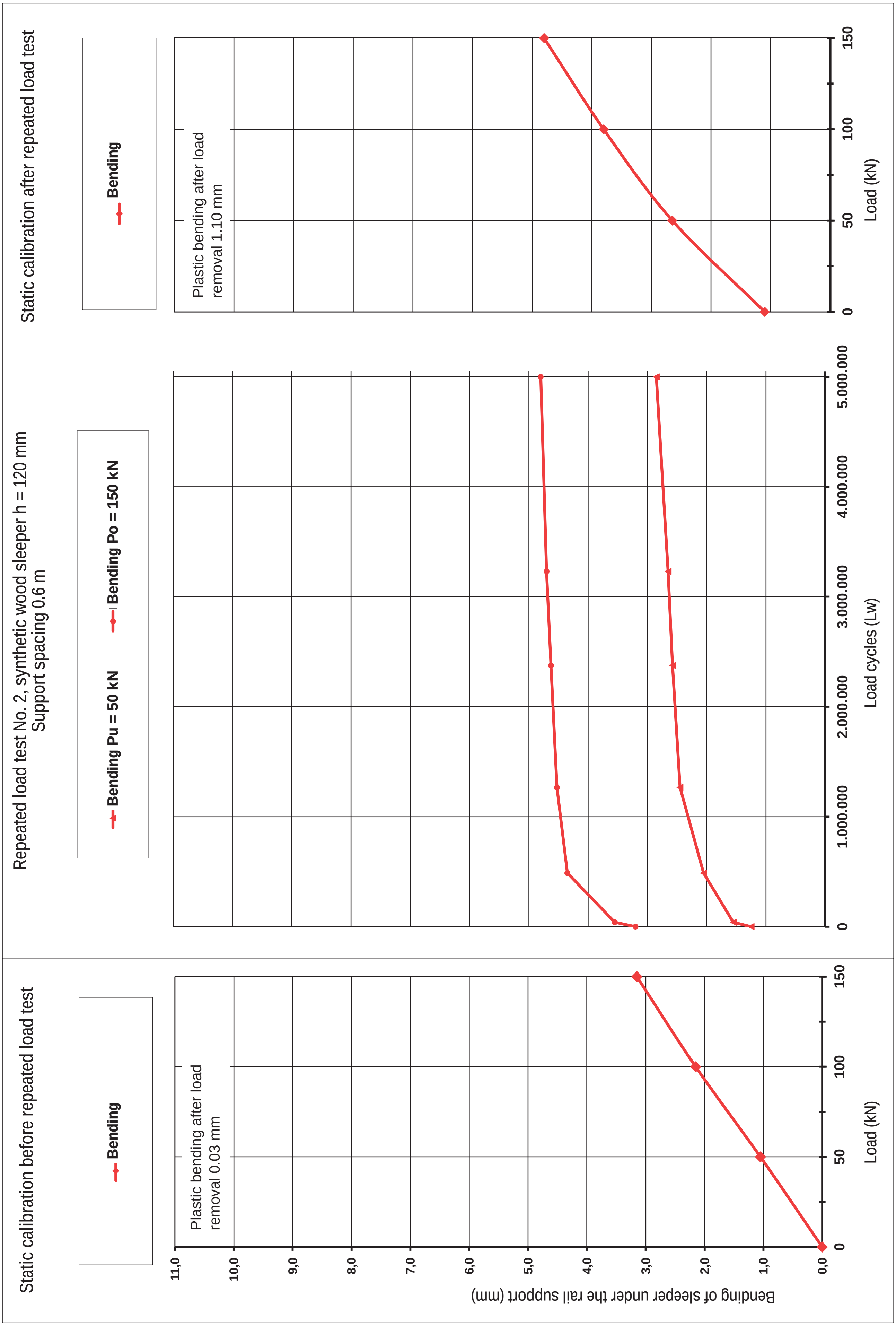
FFU with construction height of 100 mm

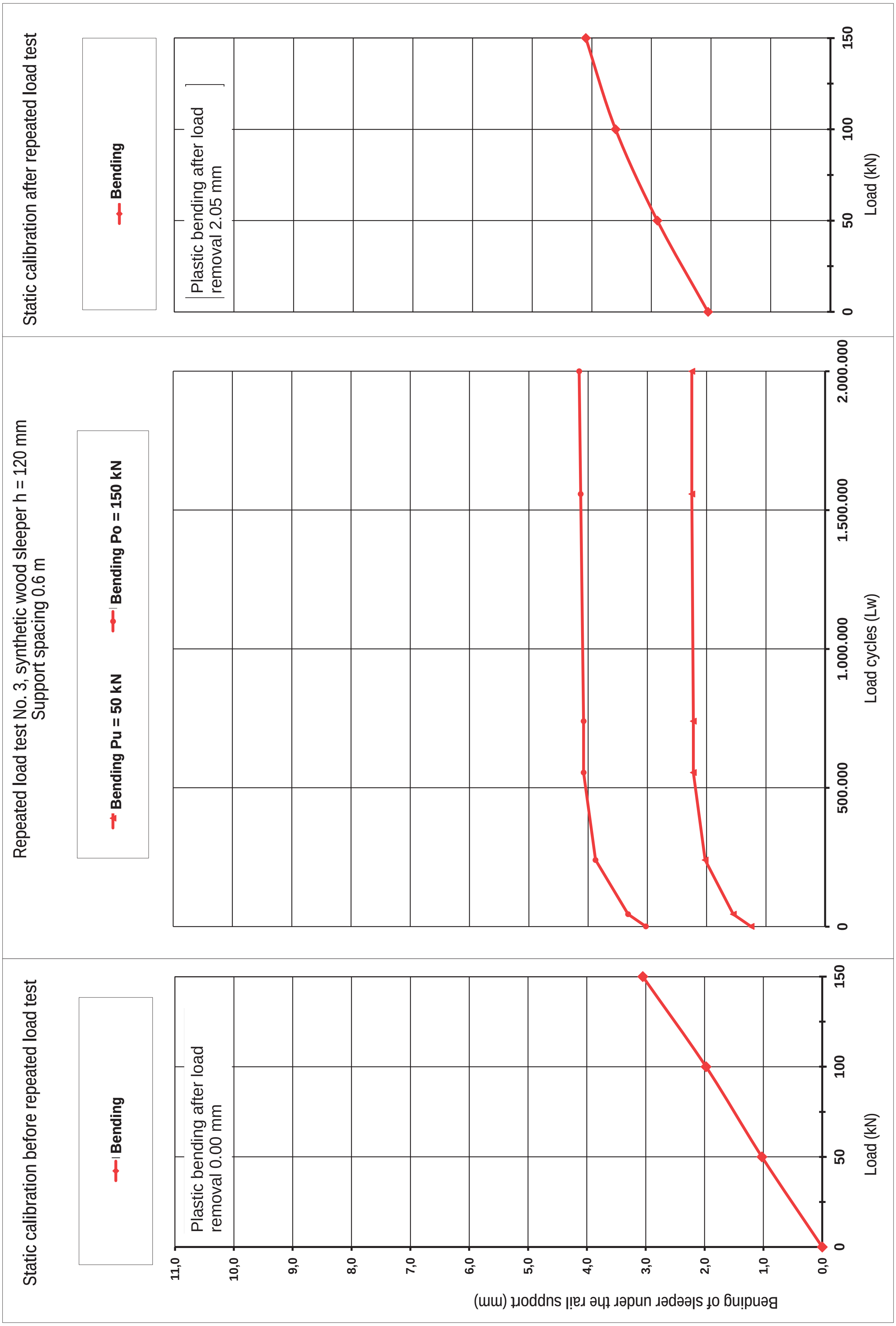



Bending of synthetic wood sleeper
Support spacing 1.5 m
Force (kN)
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
Bending (mm)
h = 100 mm
h = 120 mm
h = 160 mm

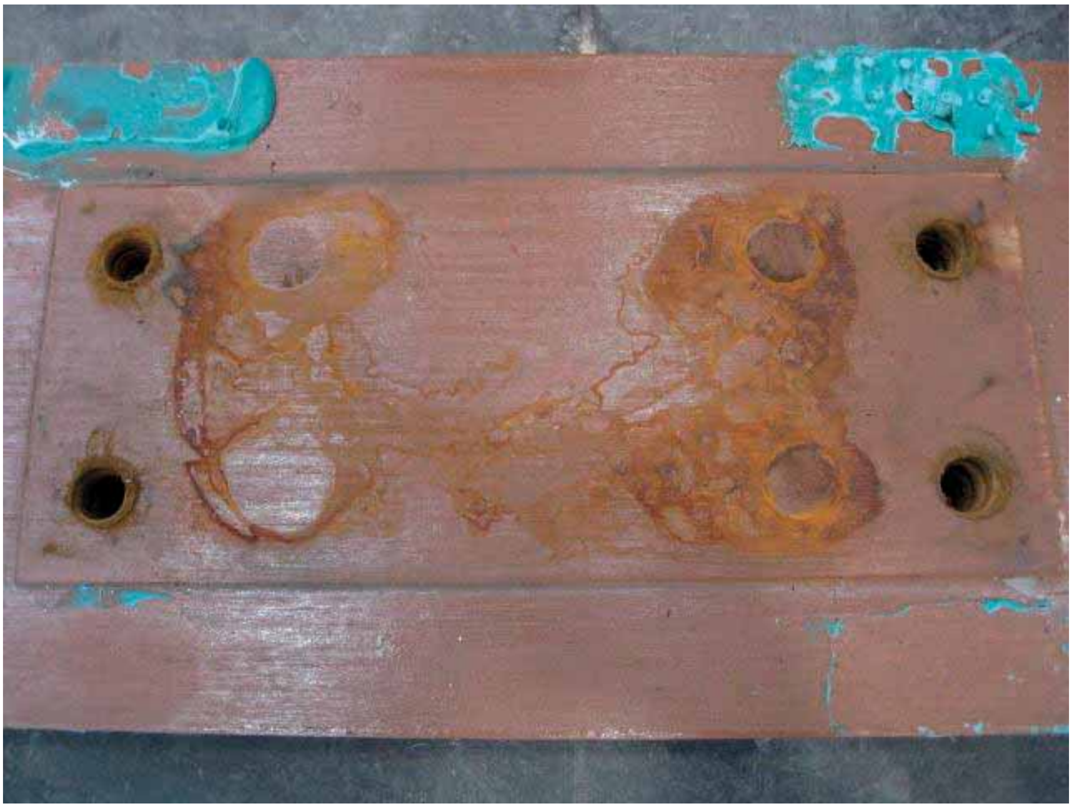

Static calibration before repeated load test
Bending
Plastic bending after load removal 0.03 mm
Bending of sleeper in sleeper centre (mm)
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
18,0
20,0
Load (kN)
0
10
20
30
40
50
60
Repeated load test synthetic wood sleeper h = 120 mm
Support spacing 1500 mm
Bending Pu = 17 kN
Bending Po = 65 kN
Load cycles (Lw)
0
500.000
1.000.000
1.500.000
2.000.000
Static calibration after repeated load test
Bending
Plastic bending after load removal 0.15 mm
Load (kN)
0
10
20
30
40
50
60

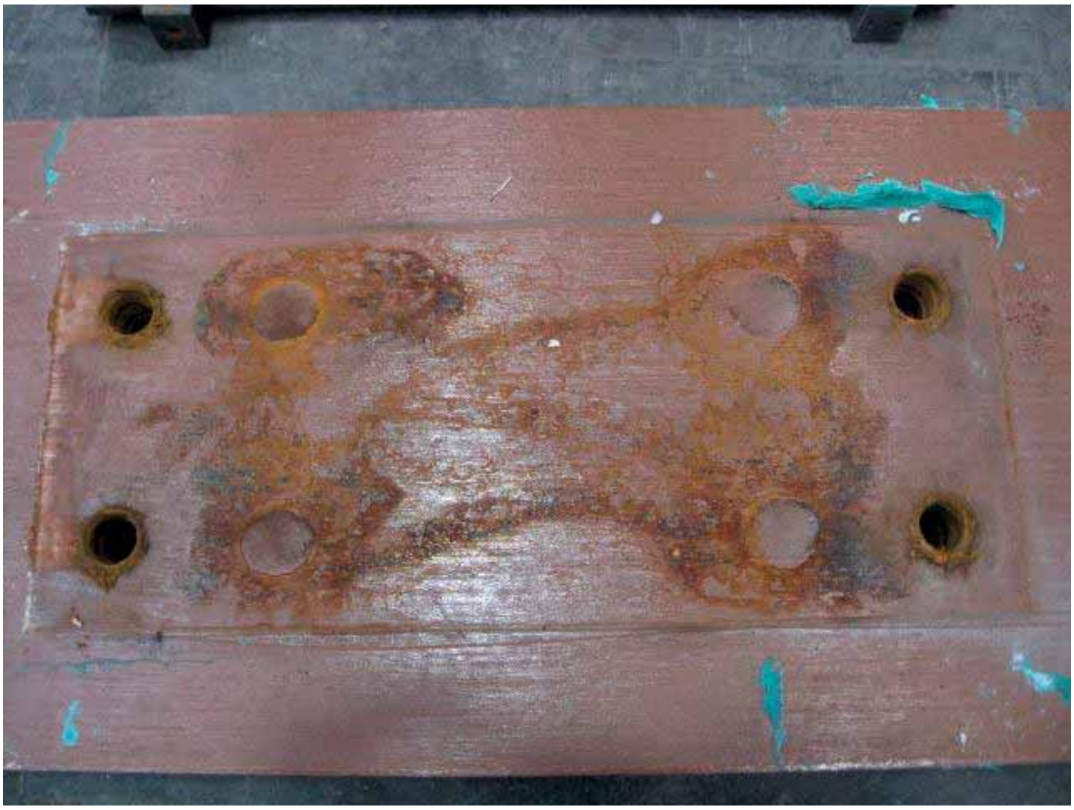

Static calibration before repeated load test
Bending
Plastic bending after load removal 0.03 mm
Bending of sleeper under the rail support (mm)
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0
8,0
9,0
10,0
11,0
Load (kN)
0
50
100
150
Repeated load test No. 1, synthetic wood sleeper h = 120 mm
Support spacing 0.6 m
Bending Pu = 30 kN
Bending Po = 65 kN
Load cycles (Lw)
0
500.000
1.000.000
1.500.000
2.000.000
Static calibration after repeated load test
Bending
Plastic bending after load removal 0.15 mm
Load (kN)
0
50
100
150


Static calibration before repeated load test
Bending
Plastic bending after load removal 0.03 mm
Bending of sleeper under the rail support (mm)
Load (kN)
Repeated load test No. 2, synthetic wood sleeper h = 120 mm
Support spacing 0.6 m
Bending Pu = 50 kN
Bending Po = 150 kN
Load cycles (Lw)
Static calibration after repeated load test
Bending
Plastic bending after load removal 1.10 mm
Load (kN)


Static calibration before repeated load test
Bending
Plastic bending after load removal 0.00 mm
Bending of sleeper under the rail support (mm)
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0
8,0
9,0
10,0
11,0
0
50
100
150
Load (kN)
Repeated load test No. 3, synthetic wood sleeper h = 120 mm
Support spacing 0.6 m
Bending Pu = 50 kN
Bending Po = 150 kN
0
500.000
1.000.000
1.500.000
2.000.000
Load cycles (Lw)
Static calibration after repeated load test
Bending
Plastic bending after load removal 2.05 mm
0
50
100
150
Load (kN)

Repeated load test on the basis of DIN EN 13481-3

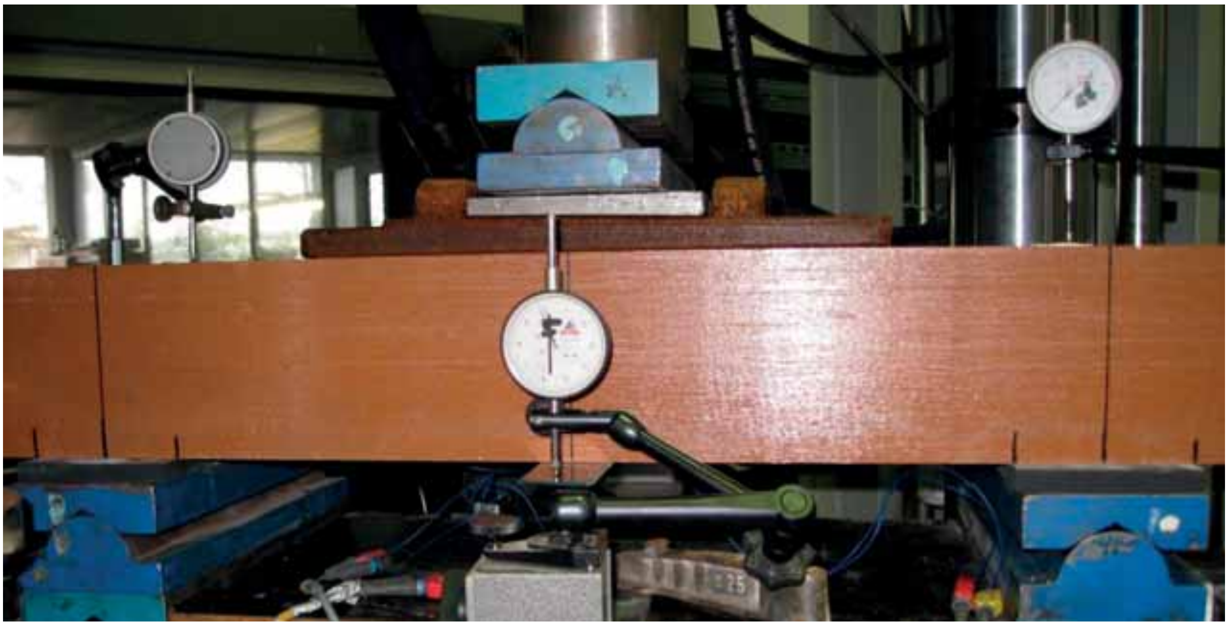




Slight plastic deformations of max. 0.23 mm at the sleeper surface following repeated load test (3.0 million load cycles)

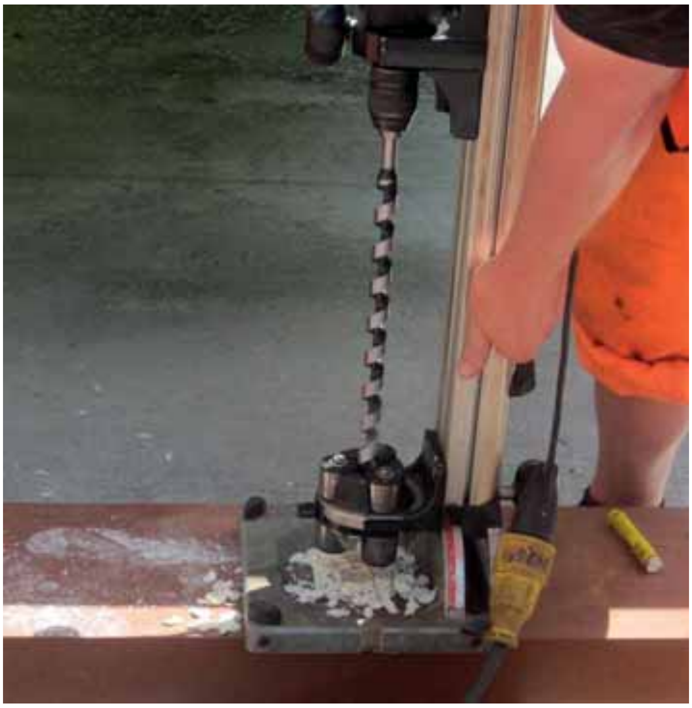
Static test in sleeper centre

Fatigue test in sleeper centre (2.0 million load cycles)



Fatigue test under rail support

Only slight plastic deformations werde ascertained under the rail supports



Making bore holes in the synthetic wood sleeper

Pulling tests

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