

**Test report no.:** 16/655/0276**Title:** Tensile and bending test on sheet piling clutch bars**Client:** SteelWall ISH GmbH  
Tassilostr. 21  
82166 Gräfelfing**1. Preliminary remark****1.1 Client's information**

Test object: STEELWALL-clutch bars, for type designation see 1.3  
Sample receipt: 2. 11. 2015 / 6. 3. 2015 / 24. 4. 2015 / 30. 3. 2016 /  
9. 5. 2016 / 25. 5. 2016  
Material: S355

**1.2 Target of the examination**

Determination of the deformation and failure behaviour of the clutch bars with bending and tensile test

**1.3 Sample designation**

<b>Sample no.</b>	<b>Profile designation</b>
1 / 2 / 3	SteelWall LBP300-20
4 / 5 / 6	SteelWall LBP300-16
7 / 8 / 9 / 10	SteelWall LBP180-12
11 / 12 / 13	SteelWall LBP180-10
14 / 15 / 16	SteelWall LBP100-10
17 / 18	SteelWall FD180-12
19 / 20	SteelWall FD300-12
21 / 22	SteelWall PZM-US / PZF-US

#### 1.4 Examinations to be performed

- Tensile test at the part
- Part bending test, cantilevered
- Part-bending test, three-point bend

## 2. Results

### 2.1 Tensile test on the part

To determine the failure behaviour under tensile stress, tensile tests were performed on paired clutch bars. To perform these tests a standard tensile test machine (type Schenck-Trebel UPM400) was used. The clutch bars were cut into stripes approx. 50 mm wide, paired, clamped and axial tensile stress was applied, with continually increased pulling force until failure of the connection between the clutch bars by deformation or until break of a part. The tensile test essentially follows ISO 6892-1:2009 B, with a constant tension increase speed between 6 MPa/s and 60 MPa/s.

In order to take up the samples of profile types LBP100-10 and PZM-US / PZF-US in the clamping device of the test machine, the corresponding extension pieces were welded to the clutch bars (see figure 15). The tensile tests on the individual clutch bars are documented in the figures 1 to 16, each with a picture before and after the test.

Referring the maximum force achieved in the test to the length of the tested clutch bar leads to the length-related maximum resilience of the respective tested clutch bar as a characteristic value to determine such connections.

The results of the tensile tests performed are shown in the following table in typical international units; for the test setup and failure behaviour, see the following figures 1 to 16.



Table 1: Tensile tests on parts, results

<b>Sample no.</b>	<b><math>F_m^*</math> [kN] / [lb]</b>	<b>Length of the clutch bar [mm] / [in]</b>	<b>Length-related maximum resilience [kN/m] / [t/m] / [kip/in]</b>
1 (LBP300-20)	140.5 / 31,585.63	51.2 / 2.016	2,744.14 / 279.82 / 15.67
4 (LBP300-16)	92.5 / 20794.81	50.6 / 1.992	1,828.06 / 186.41 / 10.44
7 (LBP180-12)	76.5 / 17,197.87	50.9 / 2.004	1,502.95 / 153.26 / 8.58
11 (LBP180-10)	51.0 / 11,465.25	49.7 / 1.957	1,026.16 / 104.64 / 5.86
14 (LBP100-10)	49.0 / 11,015.63	50.0 / 1.969	980.00 / 99.93 / 5.60
17 (FD180-12)	298.0 / 66,993.00	51.0 / 2.008	5,843.14 / 595.83 / 33.37
19 (FD300-12)	317.5 / 71,376.77	50.3 / 1.980	6,312.13 / 643.66 / 36.04
21 (PZM/PZF)	102.0 / 22,930.49	49.7 / 1.957	2,052.31 / 209.28 / 11.72

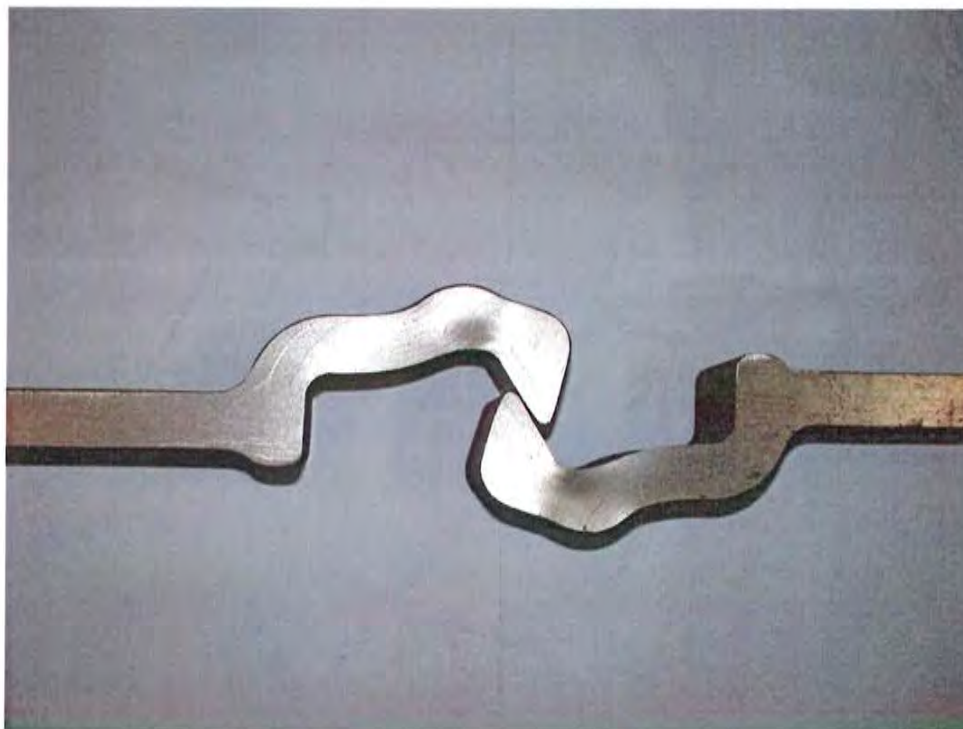
Table 1: Part tensile test in accordance with ISO 6892-1:2009 B;

\*Maximum force until failure by deformation or break.

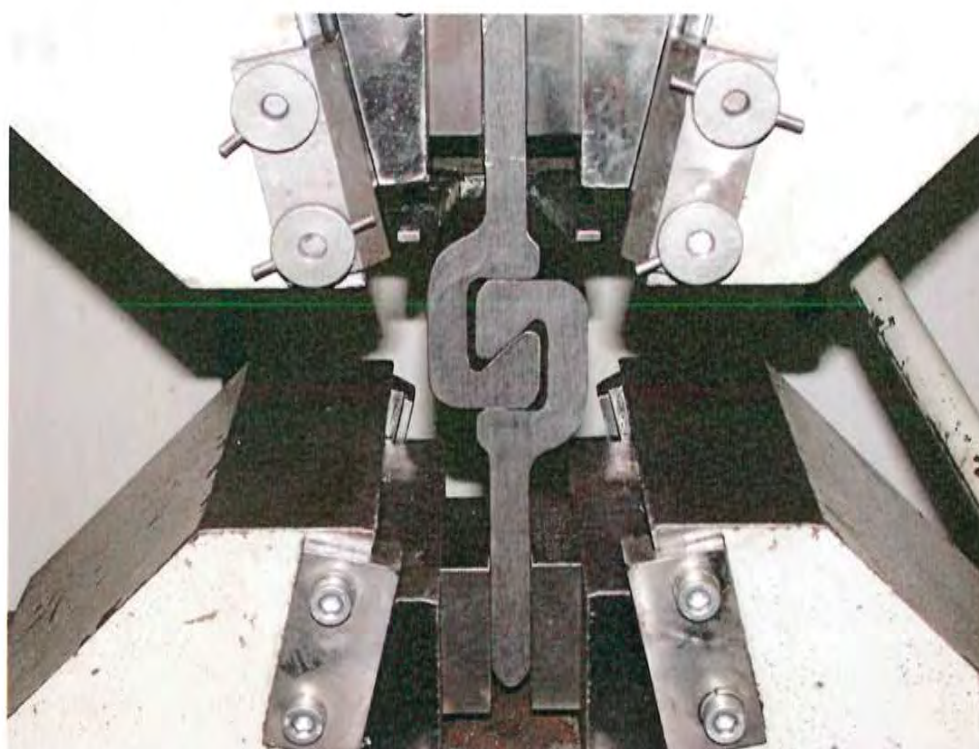
Processor / date: M. Renner / 15 April 2015, 06 November 2015, 11 April 2016 and 01 June 2016



Figure 1:  
Overview photo, sample no. 1 (LBP300-20),  
Test setup

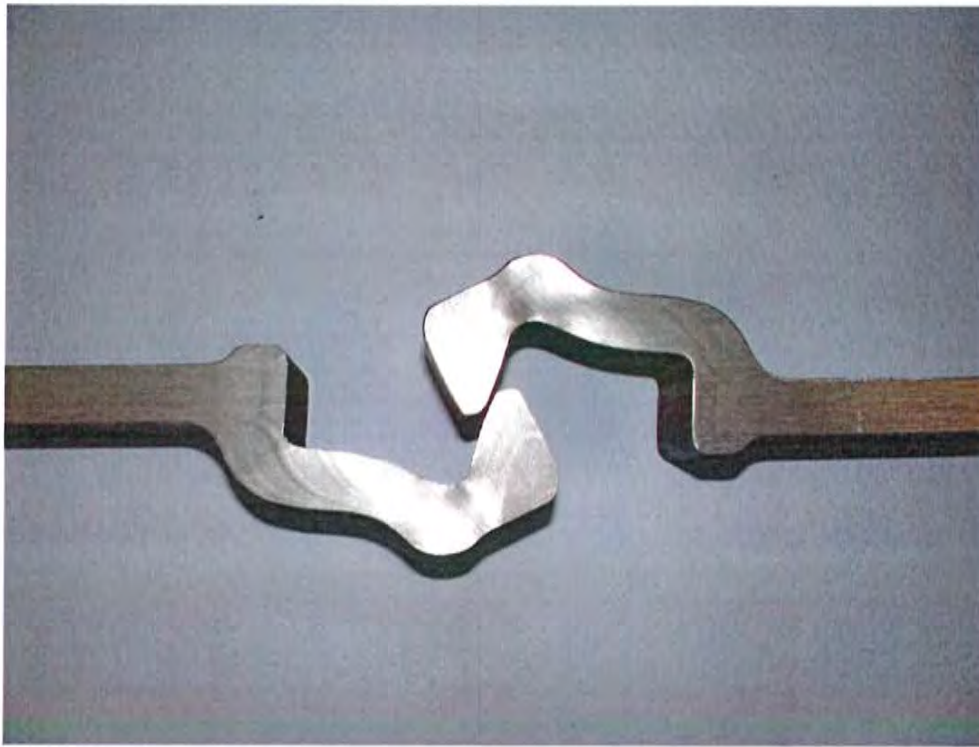


*Figure 2:*  
Overview photo, sample no. 1 (LBP300-20),  
after test, failure by deformation

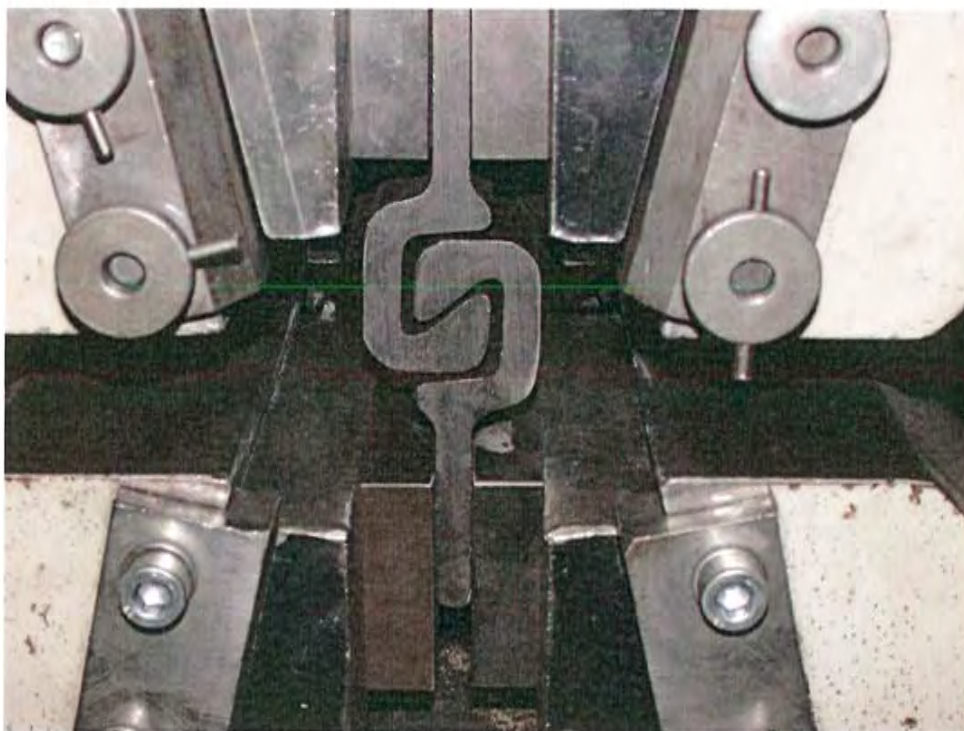


*Figure 3:*  
Overview photo, sample no. 4 (LBP300-16),  
Test setup

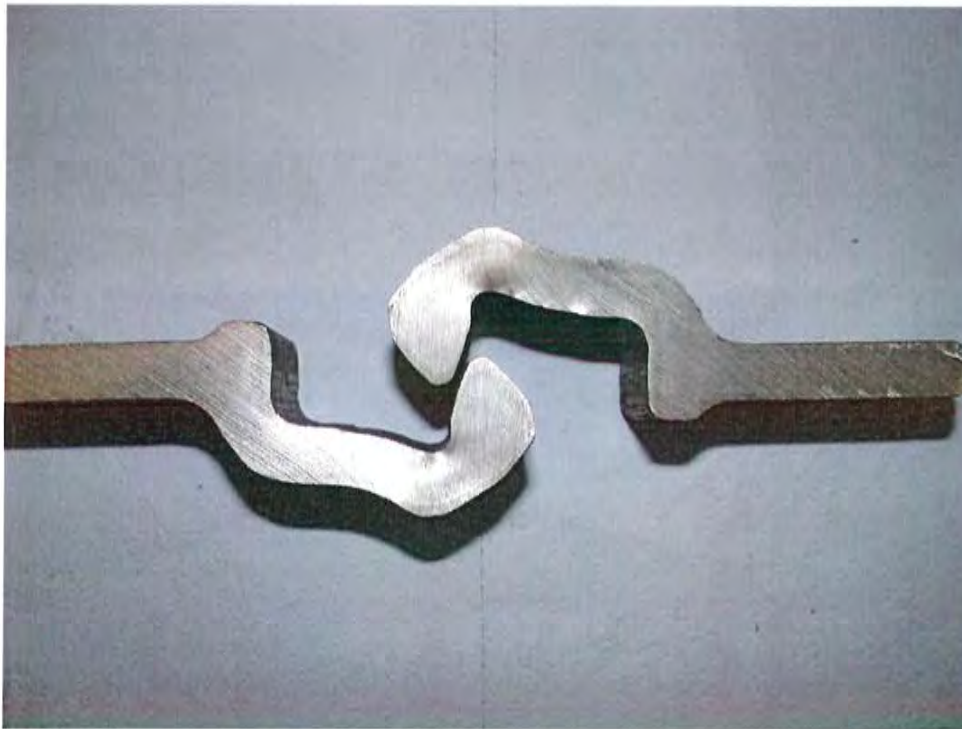




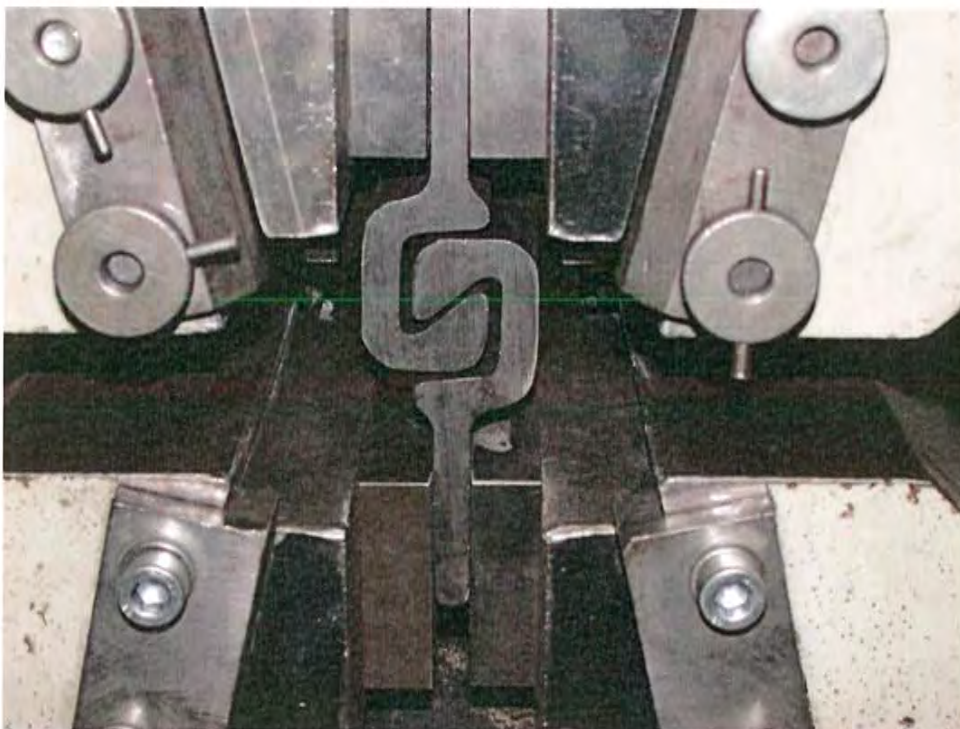
*Figure 4:*  
Overview photo, sample no. 4 (LBP300-16),  
after test, failure by deformation



*Figure 5:*  
Overview photo, sample no. 7 (LBP180-12),  
Test setup

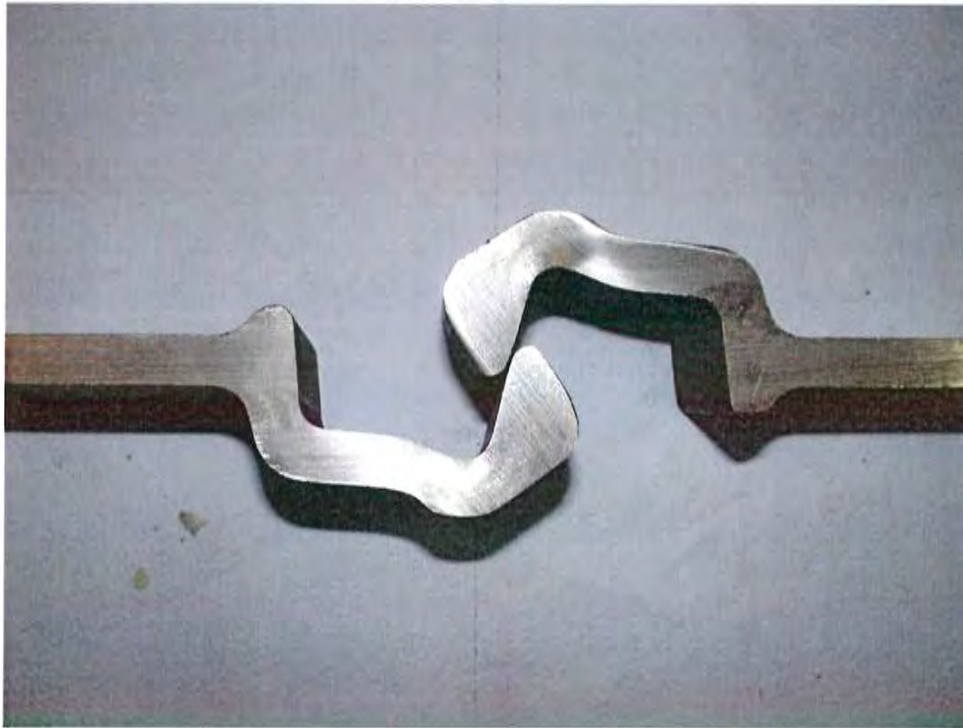


*Figure 6:*  
Overview photo, sample no. 7 (LBP180-12),  
after test, failure by deformation



*Figure 7:*  
Overview photo, sample no. 11 (LBP180-10),  
Test setup





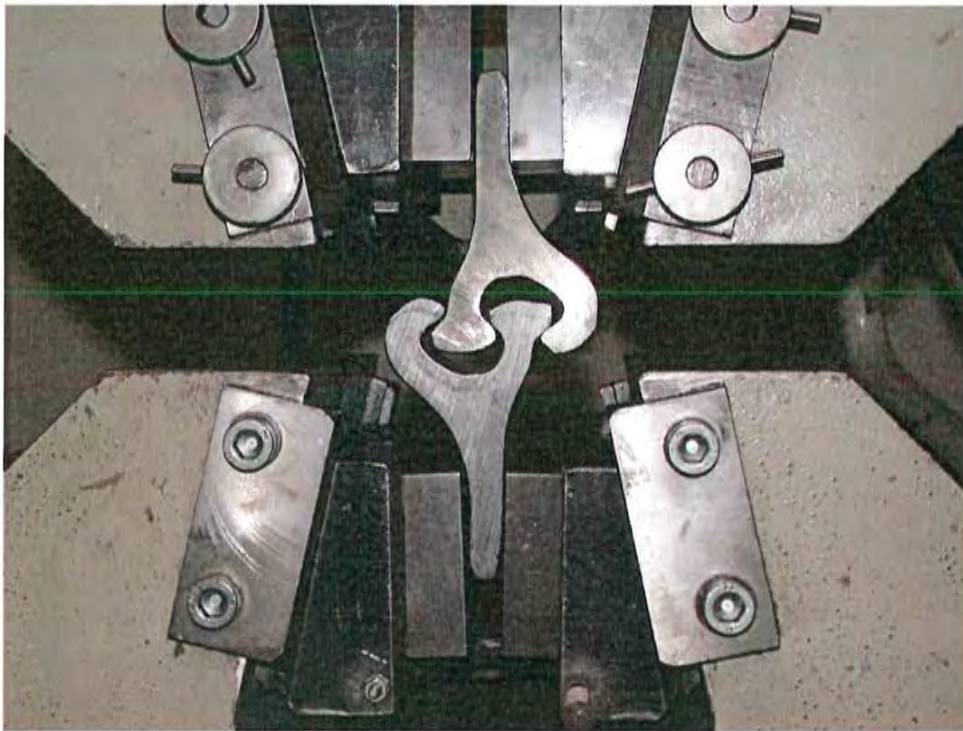
*Figure 8:*  
Overview photo, sample no. 11 (LBP180-10),  
after test, failure by deformation



*Figure 9:*  
Overview photo, sample no. 14 (LBP100-10),  
Test setup



*Figure 10:*  
Overview photo, sample no. 14 (LBP100-10),  
after test, failure by deformation



*Figure 11:*  
Overview photo, sample no. 17 (FD180-12),  
Test setup





Figure 12:  
Overview photo, sample no. 17 (FD180-12),  
after test, failure by deformation

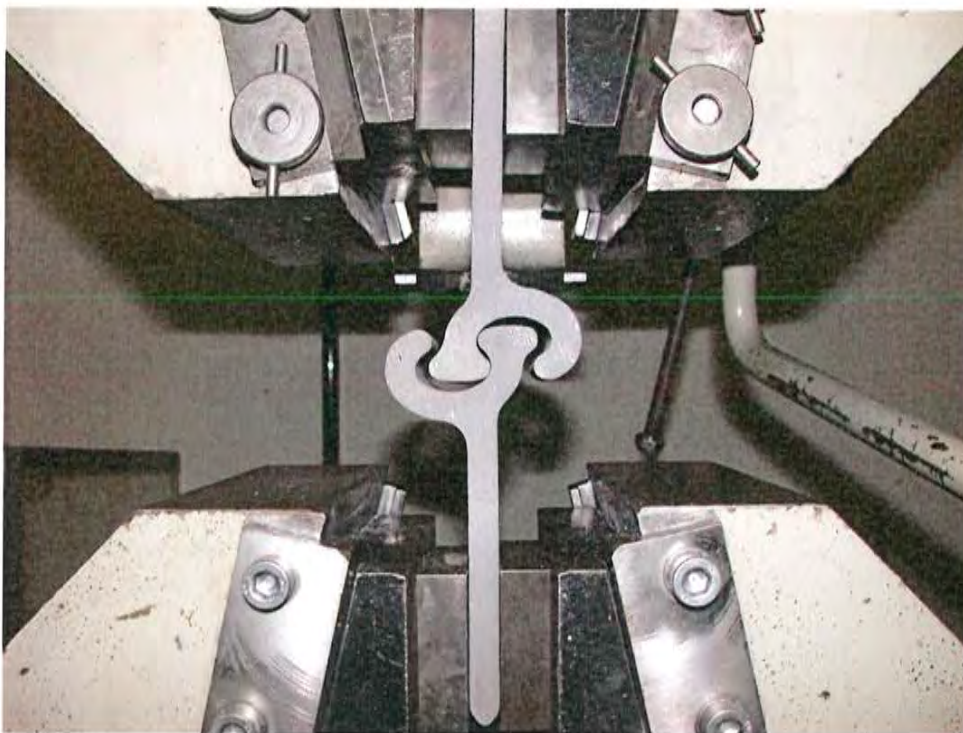


Figure 13:  
Overview photo, sample no. 19 (FD300-12),  
Test setup

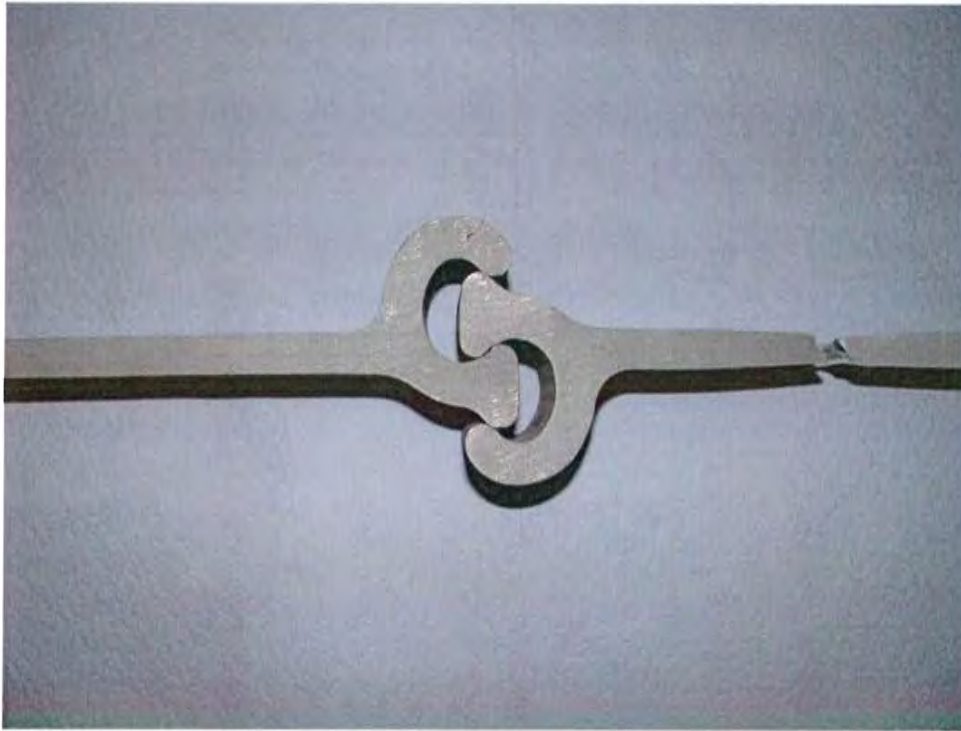


Figure 14:  
Overview photo, sample no. 19 (FD300-12),  
after test, failure by break

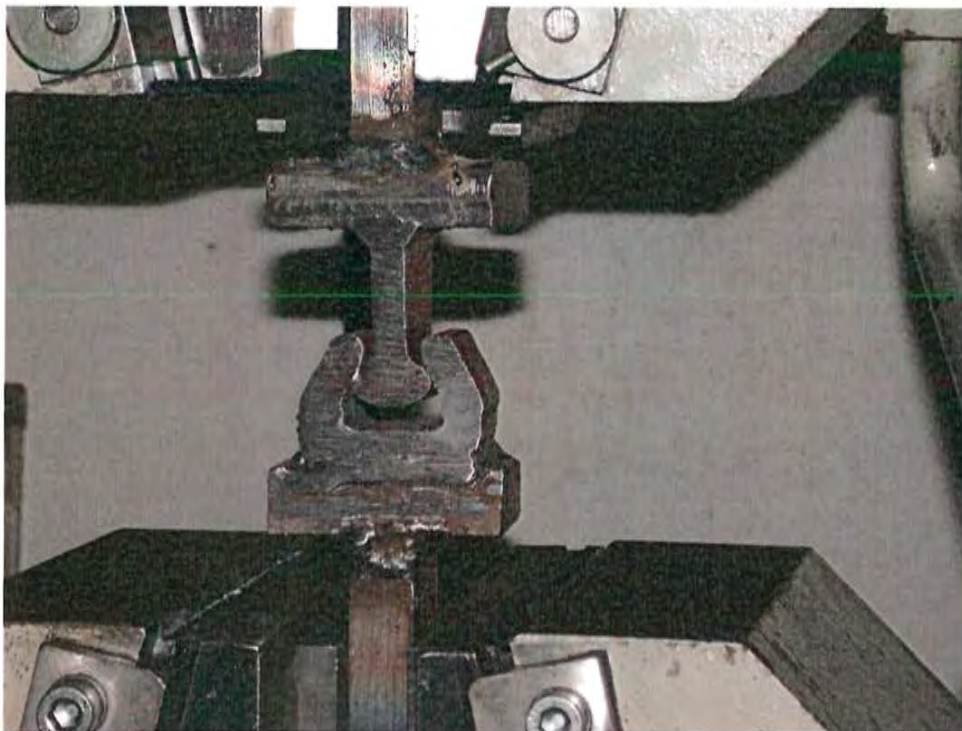


Figure 15:  
Overview photo, sample no. 21 (PZM/PZF),  
Test setup





*Figure 16:*  
Overview photo, sample no. 21 (PZM/PZF),  
after test, failure by deformation

## 2.2 Part-bending test

To review behaviour under bending stress, the corresponding tests were performed on the clutch bars.

The situation of fixed clamping of one clutch bar with bending stress by applying the respective force at the free end of the counterpart was simulated first. The clutch bar must transfer the bending stress. In light of the actual parts, this corresponds to the situation of a fixed sheet piling element to which another element is paired and turnable in the connection to simulate position deviations within the driving situation of sheet piles, beams or pipes.

Secondly a three point bending test was performed, where a bending stamp pushed on the paired clutch bars and support was provided by the welded ends of the clutch bars. This test simulates force applications in the driving procedure as well.

The tests were performed in accordance with the tensile test at approx. 50 mm long sections of the lock profiles again and the same universal testing machine Schenck-Trebel UPM400 was used.

### 2.2.1 Part-bending test, cantilevered-

To take up the clutch bar pair, one was welded to a sheet, which was screwed to the supporting block (fixed clamping). A bending mandrel with diameter 40 mm was chosen as bending stamp. The point of attack for the bending stamp is at the outside of the second clutch bar. The maximum occurring force  $F_m$  at deformation during the test performance was determined as well. Figures 17, 20, 23, 26, 29 and 32 show the respective test setup and the samples before the bending test. Figures 18, 19, 21, 22, 24, 25, 27, 28, 30, 31, 33 and 34 document the respective clutch bar after the bending test. The deformation in this stress only took place in the area of the welding vane and the welding connection in all samples. The clutch bars did not show any recognizable deformation. The results from these part bending tests can be taken from the following table in typical, internationally common units.

Table 2: Part bending tests, cantilevered, results

<b>Sample no.</b>	<b>Length of the clutch bar [mm] / [in]</b>	<b><math>F_m</math> [kN] / [lb]</b>	<b>Length-related maximum resilience [kN/m] / [t/m] / [kip/in]</b>
2 (LBP300-20)	50.9 / 2.004	13.3 / 2,989.96	261.30 / 26.64 / 1.49
5 (LBP300-16)	50.5 / 1.988	8.9 / 2,000.80	176.24 / 17.97 / 1.01
8 (LBP180-12)	46.6 / 1.835	7.6 / 1,708.55	163.09 / 16.63 / 0.93
9 (LBP180-12)	43.1 / 1.697	7.2 / 1,618.62	167.05 / 17.03 / 0.95
12 (LBP180-10)	50.0 / 1.969	6.0 / 1,348.85	120.00 / 12.24 / 0.69
15 (LBP100-10)	50.0 / 1.969	10.8 / 2,427.93	216.00 / 22.03 / 1.23

Table 2 is continued on the reverse





Table 2, continued

<b>Sample no.</b>	<b>Max. bending angle under stress [°]</b>	<b>Bending angle after test [°]</b>	<b>Weld, a-size [mm]</b>
2 (LBP300-20)	approx. 45	33	approx. 10
5 (LBP300-16)	approx. 45	33	approx. 6
8 (LBP180-12)	approx. 45	41	approx. 6
9 (LBP180-12)	approx. 45	42	approx. 6
12 (LBP180-10)	approx. 45	43	approx. 6
15 (LBP100-10)	approx. 45	35	approx. 6

Table 2: Part-bending test, cantilevered

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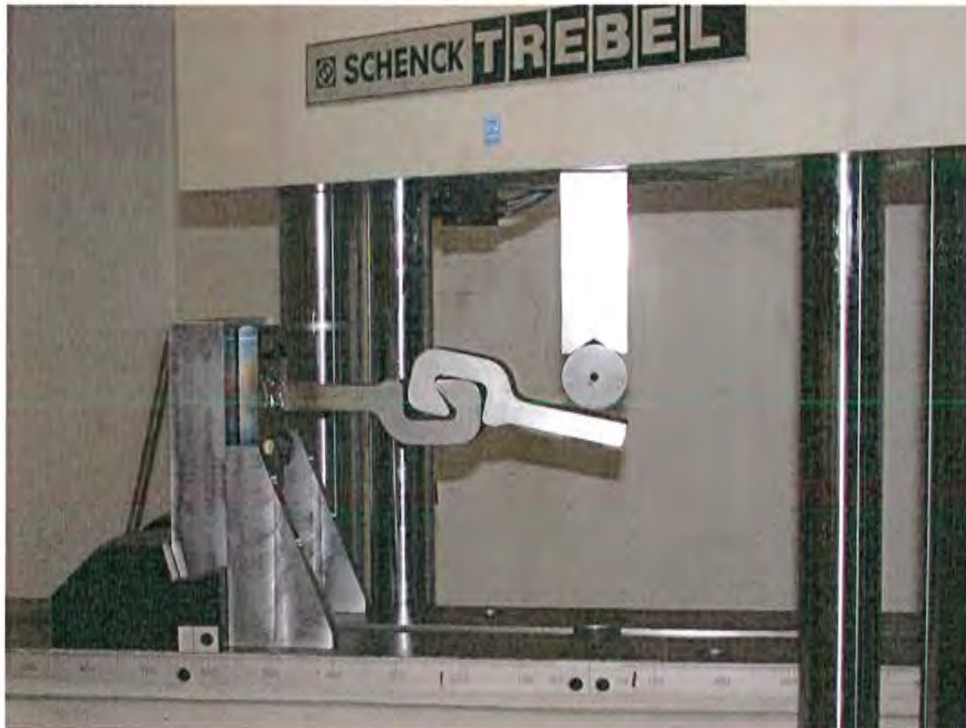
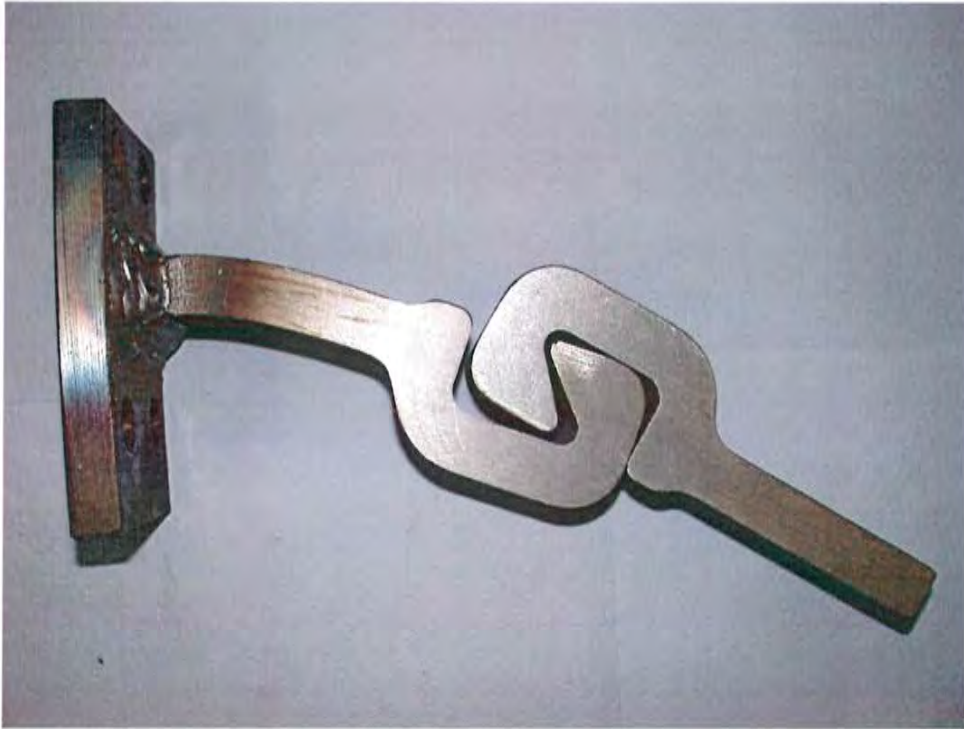
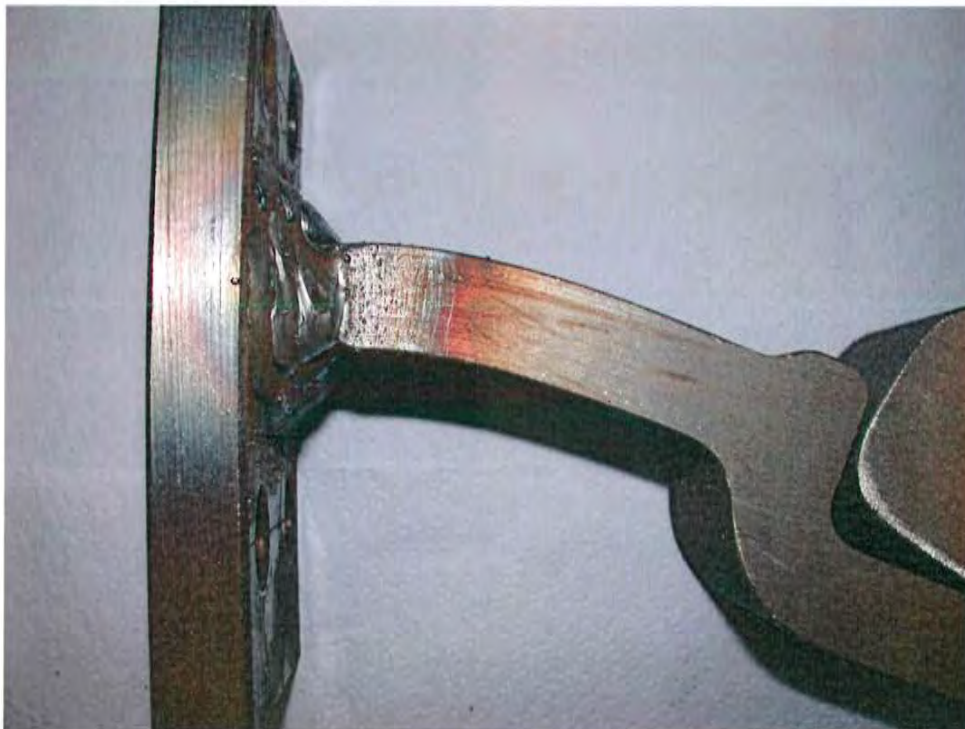


Figure 17:

Overview photo, sample no. 2 (LBP300-20),  
Test setup



*Figure 18:*  
Overview photo, sample no. 2 (LBP300-20),  
Deformation after test



*Figure 19:*  
Overview photo, sample no. 2 (LBP300-20),  
Deformation after test



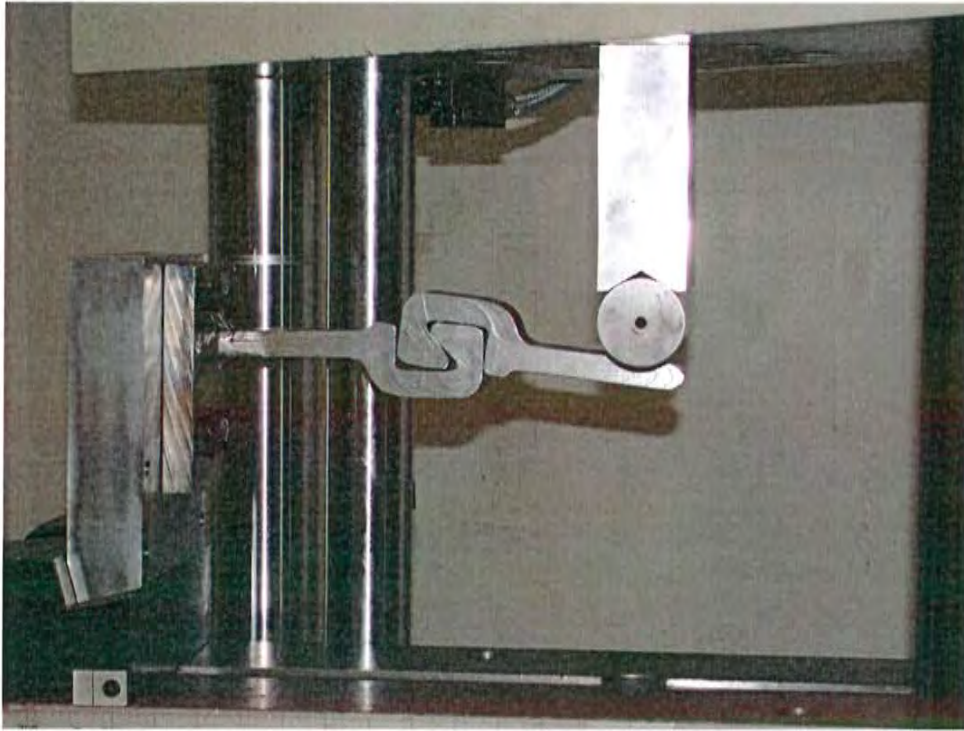


Figure 20:  
Overview photo, sample no. 5 (LBP300-16),  
Test setup

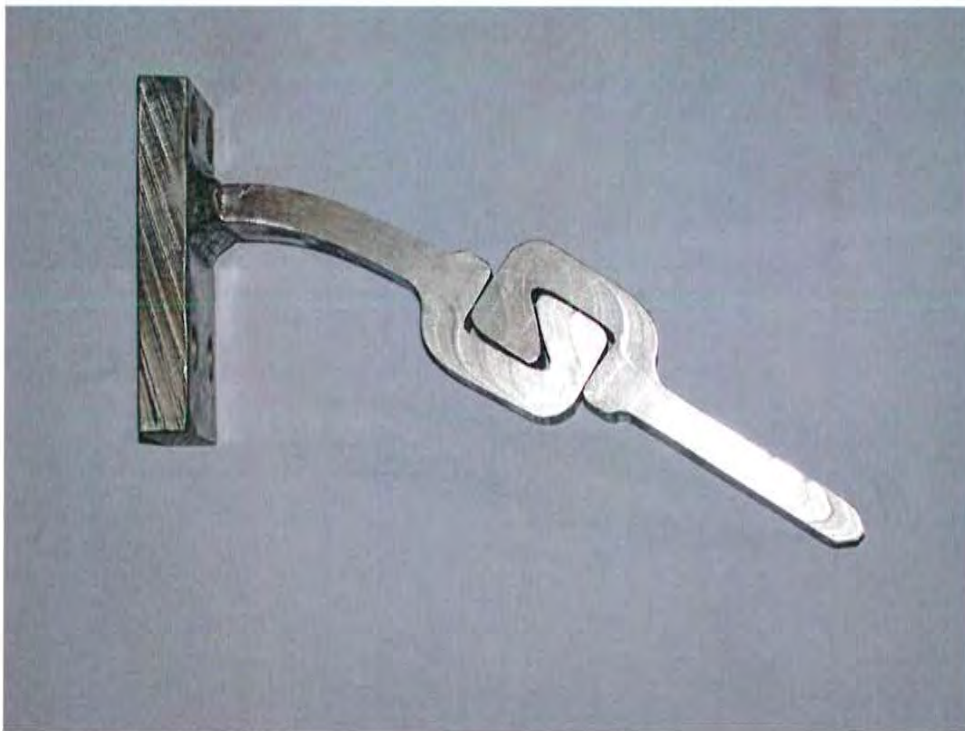
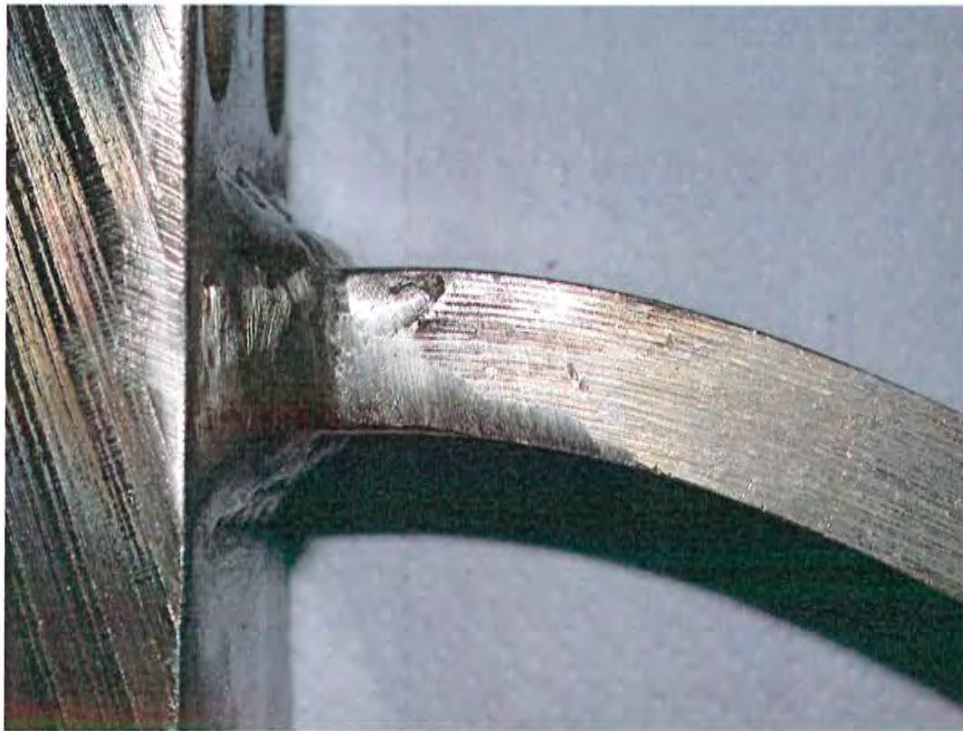
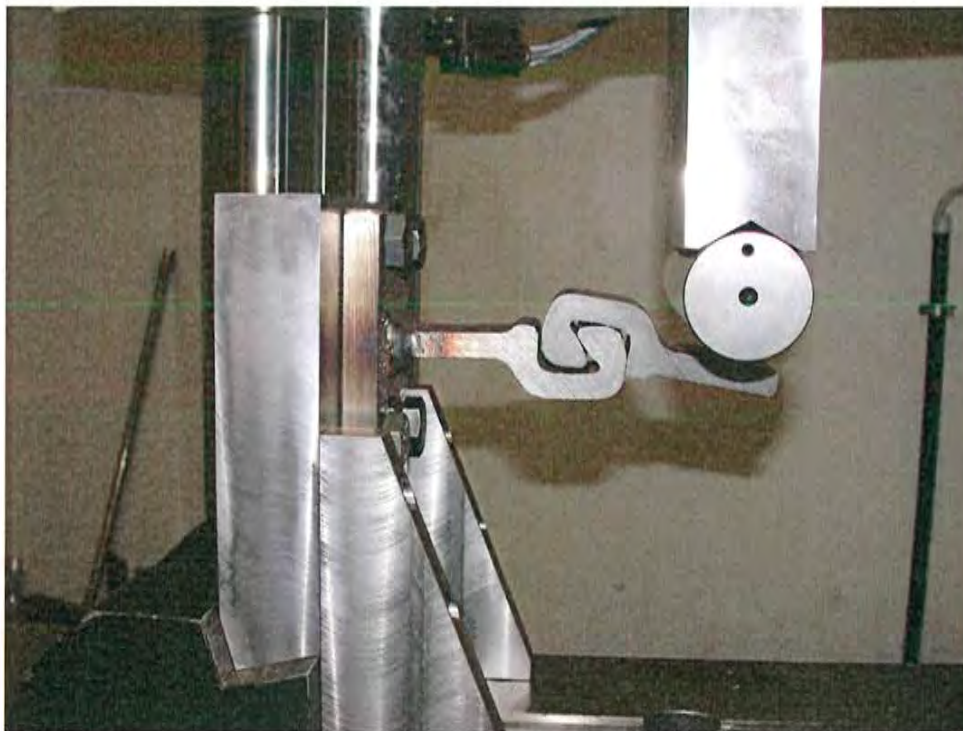


Figure 21:  
Overview photo, sample no. 5 (LBP300-16),  
Deformation after test



*Figure 22:*  
Overview photo, sample no. 5 (LBP300-16),  
Deformation after test



*Figure 23:*  
Overview photo, sample no. 8 (LBP180-12),  
Test setup



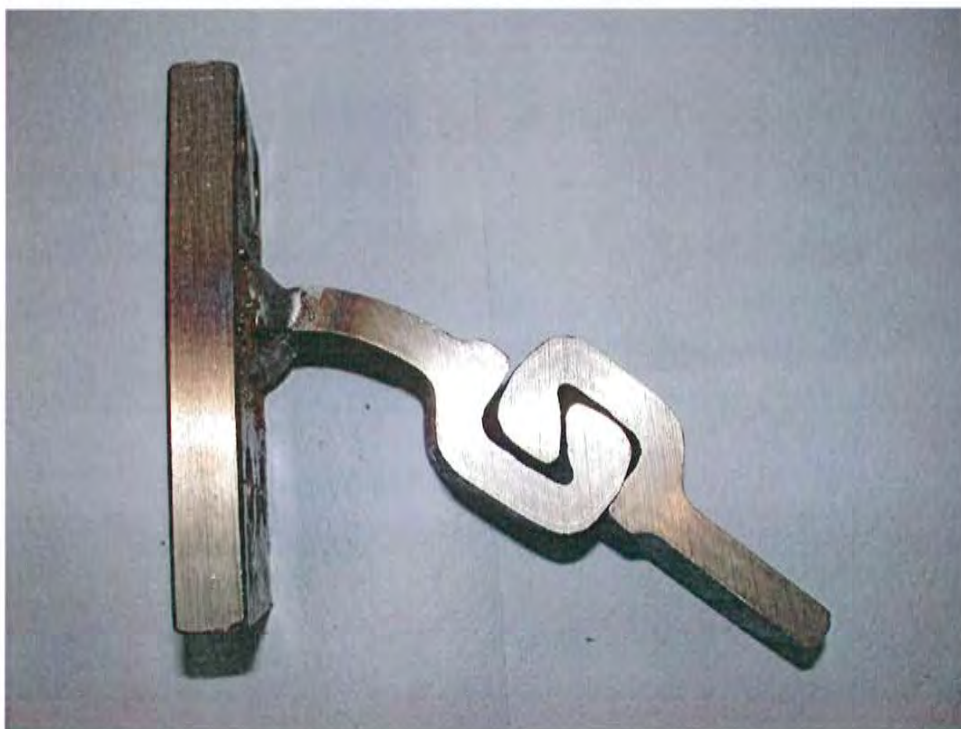


Figure 24:  
Overview photo, sample no. 8 (LBP180-12),  
Deformation after test

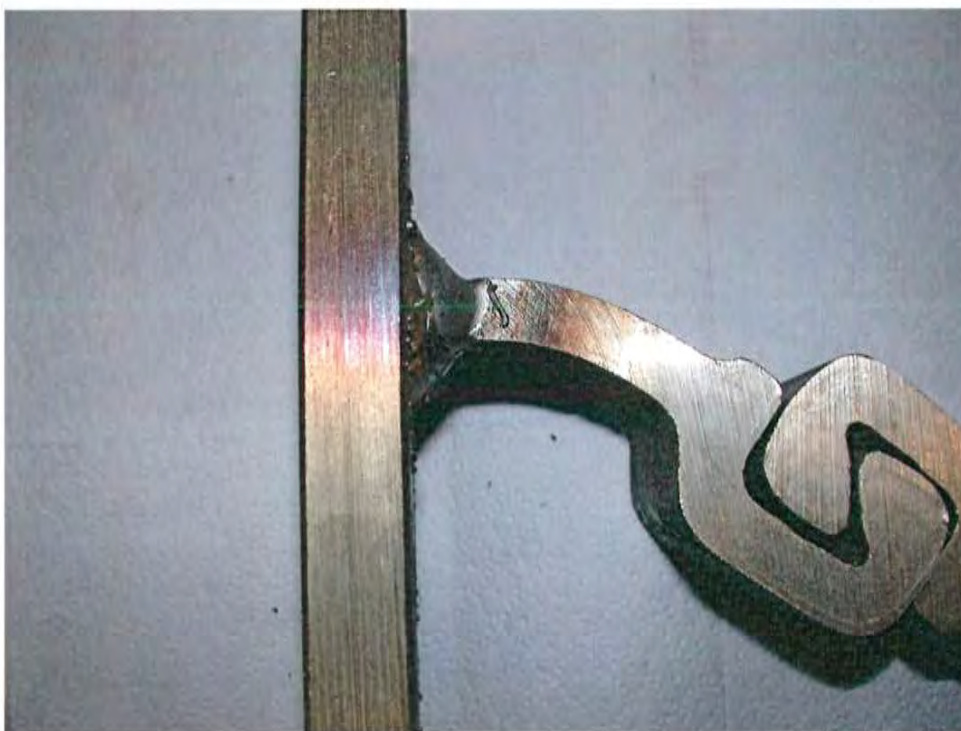


Figure 25:  
Overview photo, sample no. 8 (LBP180-12),  
Deformation after test

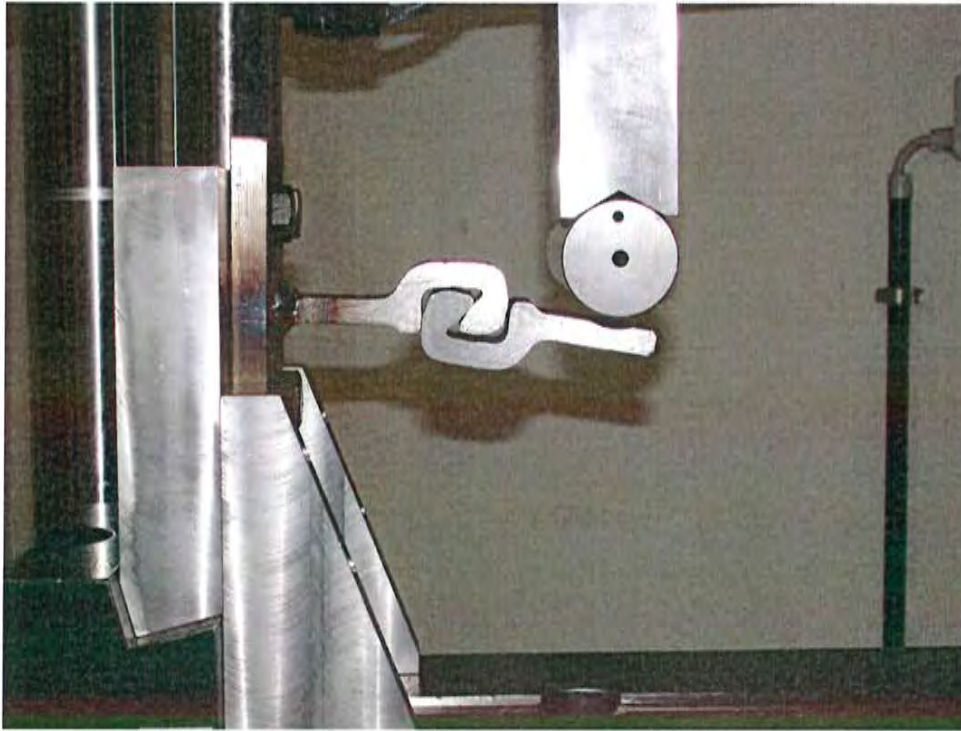


Figure 26:  
Overview photo, sample no. 9 (LBP180-12),  
Test setup

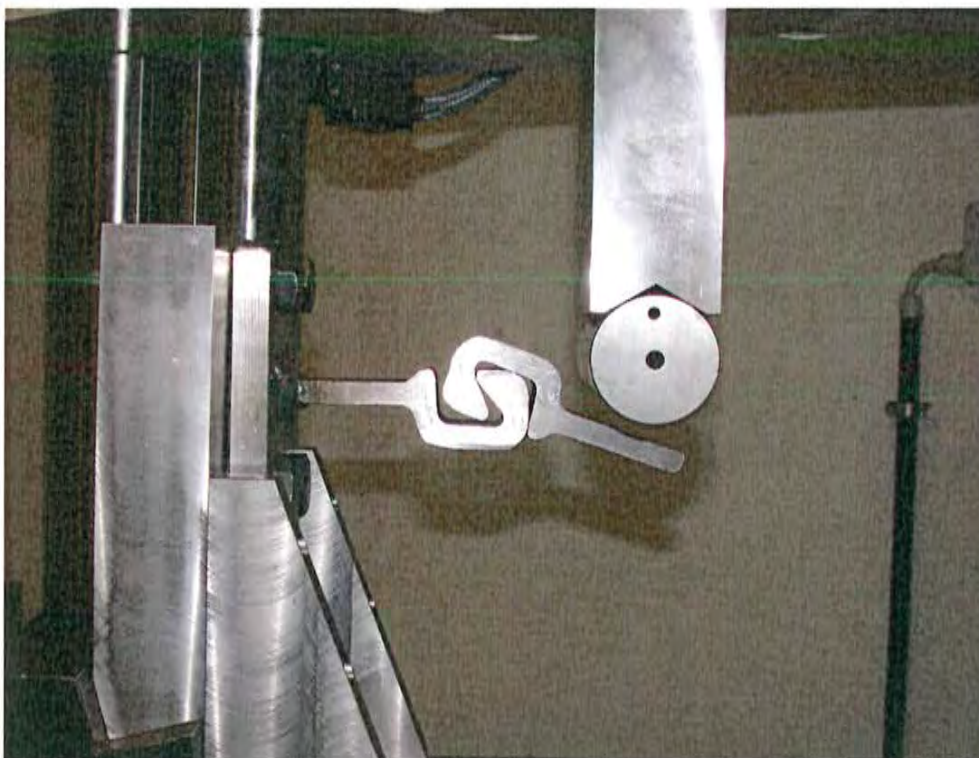


Figure 27:  
Overview photo, sample no. 9 (LBP180-12),  
Deformation after test

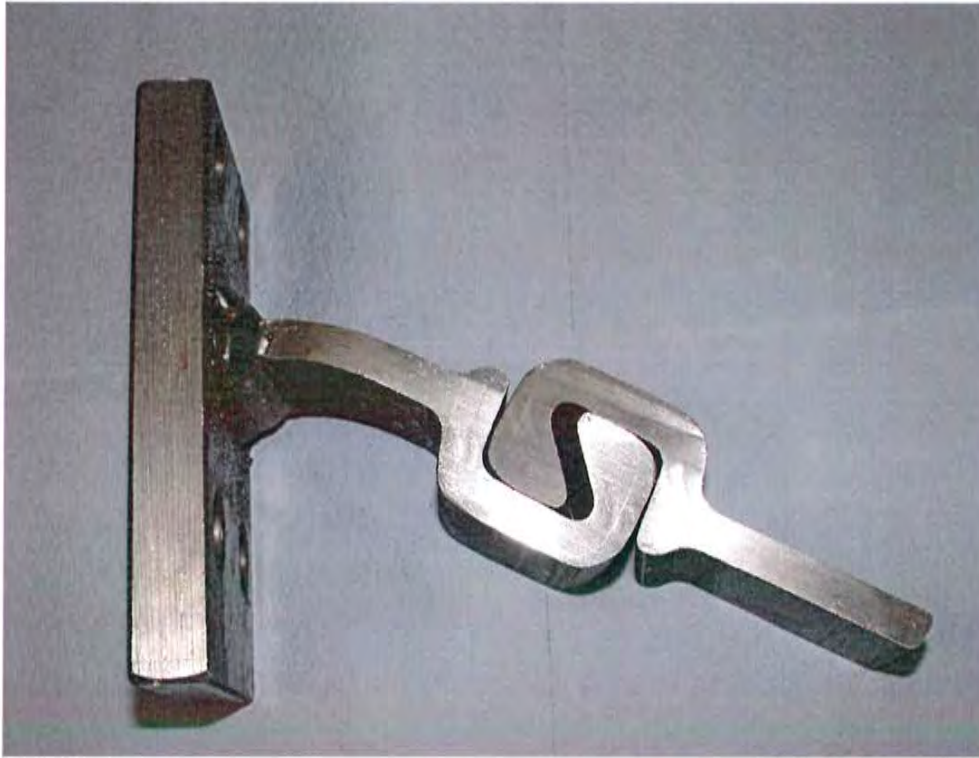




*Figure 28:*  
Overview photo, sample no. 9 (LBP180-12),  
Deformation after test



*Figure 29:*  
Overview photo, sample no. 12 (LBP180-10),  
Test setup

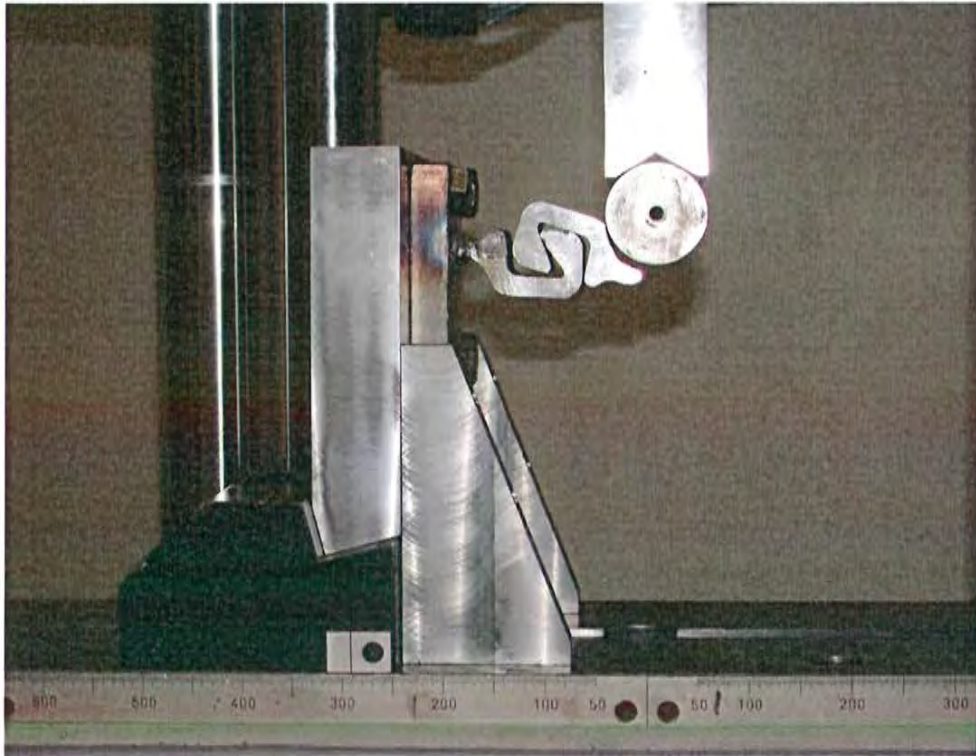


*Figure 30:*  
Overview photo, sample no. 12 (LBP180-10),  
Deformation after test



*Figure 31:*  
Overview photo, sample no. 12 (LBP180-10),  
Deformation after test





*Figure 32:*  
Overview photo, sample no. 15 (LBP100-10),  
Test setup



*Figure 33:*  
Overview photo, sample no. 15 (LBP100-10),  
Deformation after test



Figure 34:  
Overview photo, sample no. 15 (LBP100-10),  
Deformation after test

### 2.2.2 Part-bending test, three-point bending

To safely store the samples for the three-point bending test, the clutch bars PZM-US / PZF-US were extended by welding on plates. A bending mandrel with diameter 40 mm was chosen as bending stamp for profiles PZM-US/PZF-US Ø20 mm. Profile FD180-12 achieved a bending angle of approx. 105° and profile PZM-US/PZF-US one of approx. 65°. All other clutch bars were bent to approx. 180°. Figures 36 to 43 document the individual clutch bars after the bending test.

Figure 35 shows the test setup for the bending tests.

The results of the bending tests can be taken from table 3, again in typical international units.



Table 3: Part-bending tests, three-point bend, results

Sample no.	Supporting roller distance [mm]	Length of the clutch bar [mm] / [in]	$F_m$ [kN] / [lb]	Length-related maximum resilience [kN/m] / [t/m] / [kip/in]
3 (LBP300-20)	130	50.9 / 2.004	114 / 25,628.20	2,239.69 / 228.38 / 12.79
6 (LBP300-16)	130	50.6 / 1.992	65 / 14,612.57	1,284.58 / 130.99 / 7.34
10 (LBP180-12)	81	52.6 / 2.071	71 / 15,961.42	1,349.81 / 137.64 / 7.71
13 (LBP180-10)	65	49.4 / 1.945	48 / 10,790.82	971.66 / 99.08 / 5.55
16 (LBP100-10)	58	50.1 / 1.972	80 / 17,984.70	1,596.81 / 162.83 / 9.12
18 (FD180-12)	100	49.7 / 1.957	73 / 16,411.04	1,468.81 / 149.78 / 8.39
20 (FD300-12)	80	51.6 / 2.031	114 / 25,628.2	2,209.3 / 225.29 / 12.62
22 (PZM/PZF)	150	49.4 / 1.945	40 / 8,992.35	809.72 / 82.57 / 4.62

Table 3: Part-bending test, three-point bending

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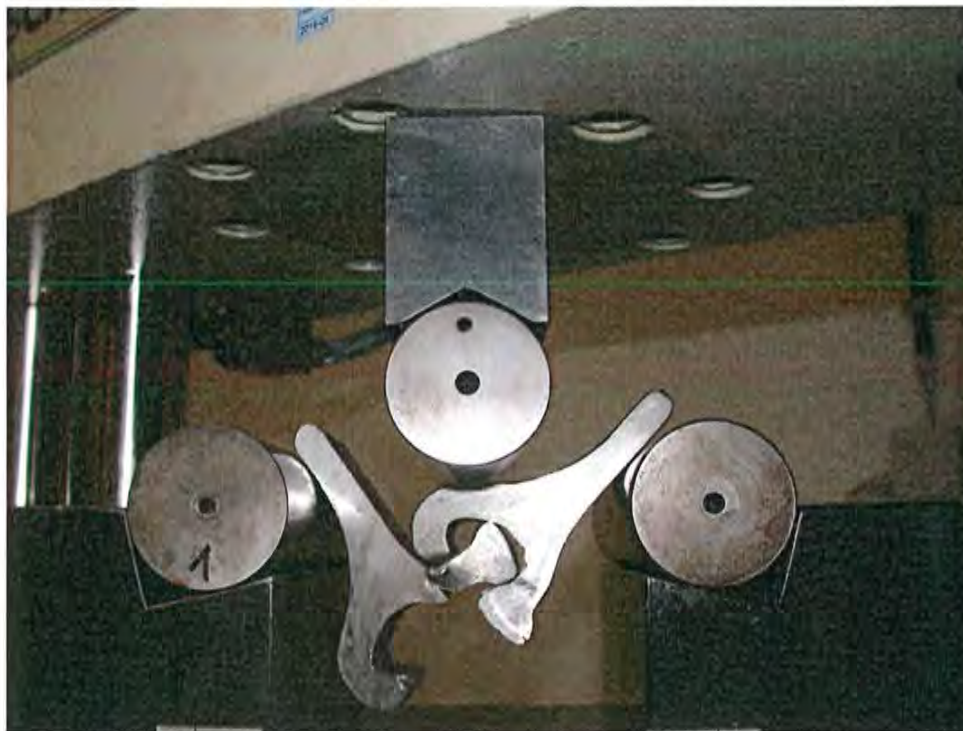


Figure 35:  
Overview photo, bending device



*Figure 36:*  
Overview photo, sample no. 3 (LBP300-20),  
Deformation with break after test



*Figure 37:*  
Overview photo, sample no. 6 (LBP300-16),  
Deformation after test





*Figure 38:*  
Overview photo, sample no. 10 (LBP180-12),  
Deformation after test



*Figure 39:*  
Overview photo, sample no. 13 (LBP180-10),  
Deformation after test



*Figure 40:*  
Overview photo, sample no. 16 (LBP100-10),  
Deformation after test



*Figure 41:*  
Overview photo, sample no. 18 (FD180-12),  
Deformation with break after test

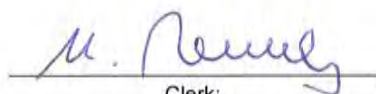




*Figure 42:*  
Overview photo, sample no. 20 (FD300-12),  
Deformation after test



*Figure 43:*  
Overview photo, sample no. 22 (PZM/PZF),  
Deformation after test



Clerk:  
M. Renner

Munich, 18 July 2016

Re/mo





Laboratory management