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Test documentation 2020-002

Load bearing tests on the Eco A roof hook for the installation of photovoltaic systems on pitched roofs

By order:

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Load bearing tests on the Eco A roof hook for the installation of photovoltaic systems on pitched roofs

1. General information

The subject of the tests documented below are load bearing tests on roof hooks of the product line EcoA manufactured by Schletter Solar GmbH. This is a roof hook consisting of two extruded profile sections which are connected by a form-locking snap-in connection with prestressing.

Fig. 1 Isometric view of the roof hook

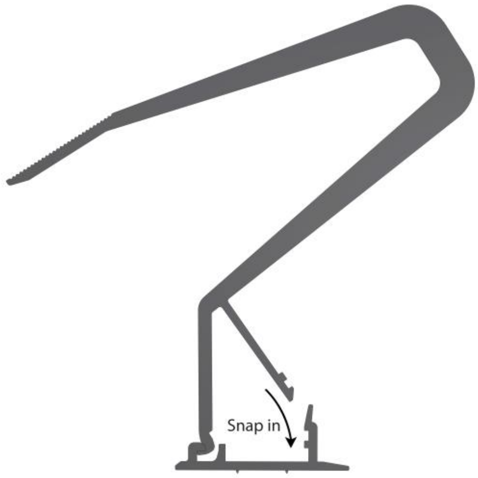

Fig. 2 Display of the snap-in mechanism

Fig. 3 Snap-in mechanism

2. Experimental Sequence

Five different test series were carried out within the scope of the examination. These include tensile and pressure tests, each in a centric position on a steel plate, and in an eccentric position mounted on a wooden beam. The test for shear carrying capacity was only carried out in an eccentric position on a wooden beam, as this is the position in which the maximum concentrated loads are applied to the wooden beam, and is thus decisive for the load capacity dimensioning. A special feature of this roof hook is the fastening to the rafter with only one screw.

4.1 Examination of tensile force (wind suction)

4.2 Examination of pressure force (dead weight, snow load)

4.3 Examination of shear force (dead weight, snow load)

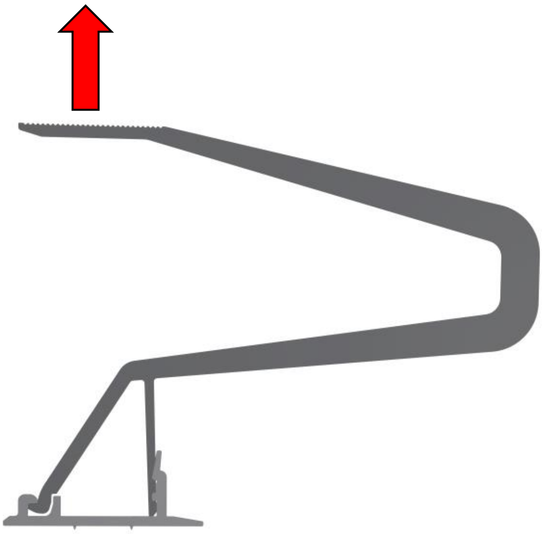

Fig. 4 Schematic display tensile test

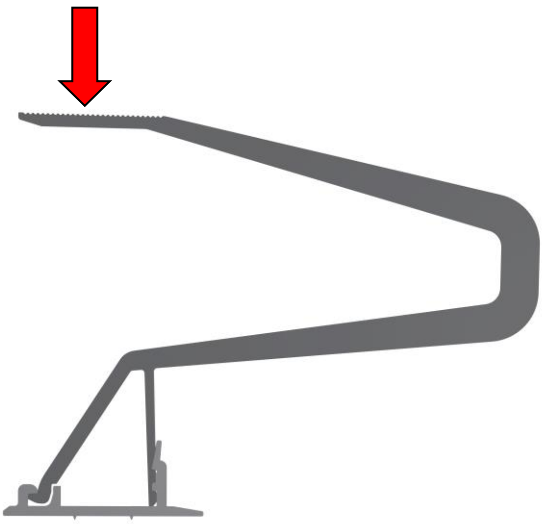

Fig. 5 Schematic display pressure test

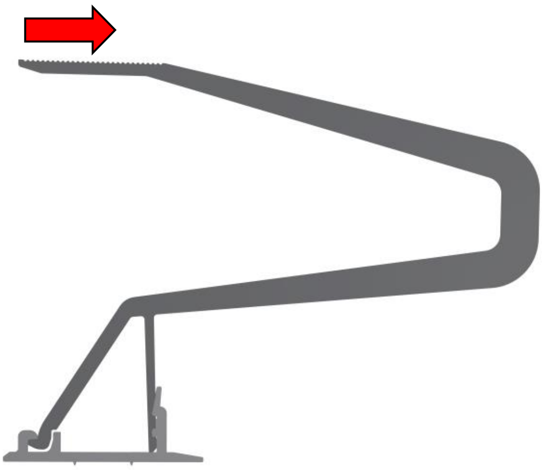

Fig. 6 Schematic display shear test

3. Testing Procedure

The tests were carried out with a servo-hydraulic testing machine manufactured by Zwick Roell. The test load and the deformation were measured and recorded electronically. The tests were carried out with a constant feed to also enable an evaluation of the post-failure behavior. The test program of the pressure and tensile tests for this connection comprised four test series with five test specimens each. For the shear tests, one series with five test specimens was carried out.

4. Experimental Results and Statistical Evaluation

As a rule, several tests deliver test curves that do not match. Depending on the material, test type and failure mechanism, variations occur in the test values. The aim of a statistical analysis is to determine the safe values which, with a defined probability, will not be undercut. In civil engineering, the 5 % fractile is the usual measure to determine a characteristic load-bearing capacity. The characteristic load-bearing capacity is determined on the basis of DIN EN 1990 Annex D. Based on a log-normal distribution of the test values, the characteristic load-bearing capacity can be determined according to the following equation: $P_{Rk} = \exp(m_y - k_n \cdot s_y)$

with: P_{Rk} characteristic load-bearing capacity

m_y Mean value of the logarithm of the test values

s_y standard deviation

k_n Fractile factor for unknown variance according to EN 1990 Table D.1

The partial safety factor for the resistance side is $\gamma_M = 1.25$

4.1.1 Examination of tensile force on wooden beam

For the examination of the tensile strength in eccentric position, the roof hook was mounted with a screw on the bottom side on a wooden beam fixed in the machine. The load was transmitted via a cross beam in the screw channel of the module bearing profile mounted above. In the course of the test, the opening of the retaining bracket increases as the load increases, and at higher loads an uplifting of the mounting plates on one side occurs. This uplifting creates a leverage effect, resulting in increased local pressing on the wooden beam. These, however, do not cause critical damage to the wooden substructure.

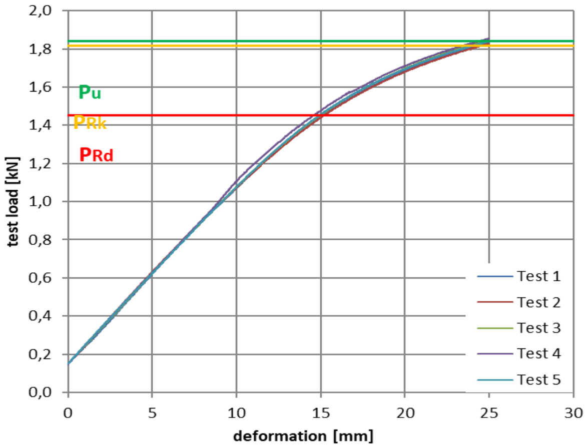

Fig. 7 Measuring records of the tensile tests

Fig. 8 Assembly at the beginning of the test

statistical evaluation according to DIN EN 1990 annex D

		x_i		$\ln x_i$	
S_1	=	1,83	kN	0,61	1,63949E-05
S_2	=	1,83	kN	0,60	4,76963E-05
S_3	=	1,85	kN	0,61	1,24657E-05
S_4	=	1,85	kN	0,62	5,60576E-05
S_5	=	1,84	kN	0,61	3,91104E-09
average value		**1,84**	**kN**	**sum**	**0,000132618**

m_y	=	0,6103235	number of tests	5
s_y	=	0,005758		
k_n	=	2,33	α_r	0,800
			β_s	4,700
P_{Rk}	=	1,82 kN	k	1,645
			v_y	0,006
P_{Rd}	=	1,45 kN	γ_M	1,250

Fig. 9 Statistical evaluation of the test series

Fig. 10 Test-setup at 1,4 kN

Fig. 11 Test-setup at 1,8 kN

Fig. 12 plastic deformation after 45mm traverse path

The measurement records of the pressure tests including the statistical evaluation to deduce characteristic values of the pressure capability and of design values are displayed in Fig. 7 and Fig. 9. The statistical evaluation is based on EN 1990 Annex Z. The partial safety factor for the resistance side is $\gamma_M = 1.25$.

4.1.2 Examination of tensile strength on steel plate

For the examination of the tensile strength in centric position the roof hook was mounted with a screw on the bottom side on a steel plate fixed in the machine. The tentative test shows that the load bearing capacity does not differ significantly from the eccentric position.

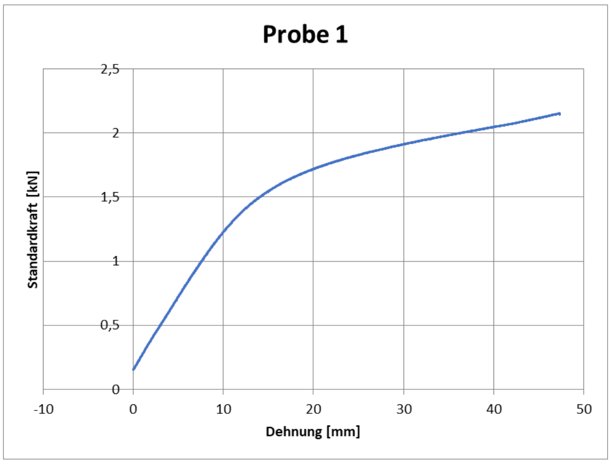

Fig. 13 Measuring record of the tentative test

Fig. 14 Assembly at the beginning of the test

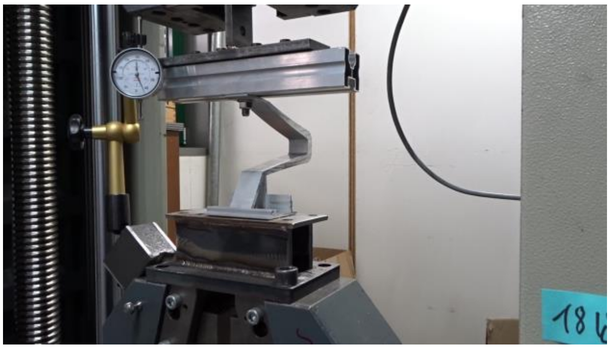

Fig. 15 Test-setup at 1,5 kN

Fig. 16 Test-setup at 1,7 kN

4.2.1 Examination of pressure on wooden beam

For the examination of the pressure strength in eccentric position, the roof hook was mounted with a screw on the bottom side on a wooden beam fixed in the machine. The load was transmitted via a steel plate, to the module bearing profile mounted on the upper side. In the course of the test, the retaining bracket closes increasingly with an increasing load. At higher loads, the support plate tilts so that the wooden beam receives more load from one edge. This, however, does not lead to critical damage to the wood substructure.

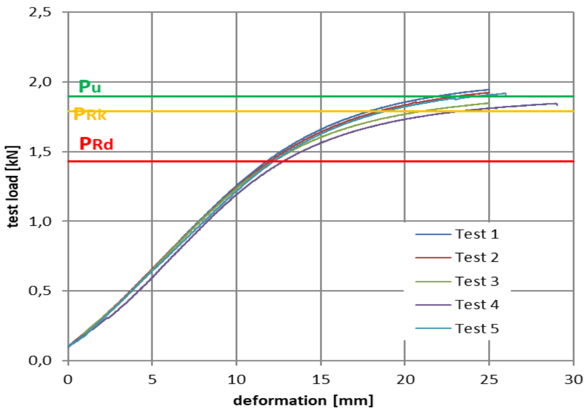

Fig. 17 Measuring records of the pressure tests

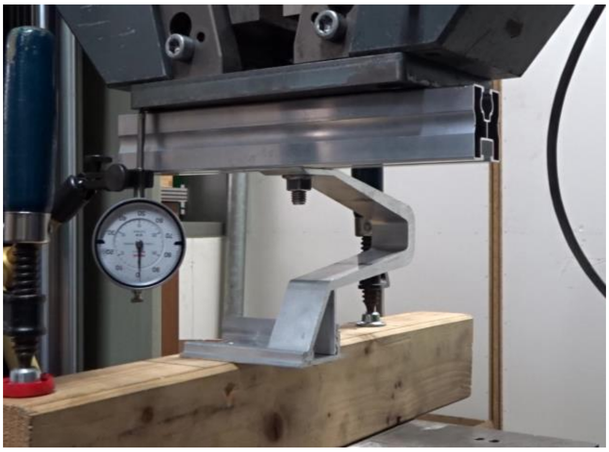

Fig. 18 Assembly at the beginning of the test

statistical evaluation according to DIN EN 1990 annex D

		x_i		$\ln x_i$	
S_1	=	1,95	kN	0,67	0,000680678
S_2	=	1,92	kN	0,65	0,000222562
S_3	=	1,85	kN	0,61	0,000673339
S_4	=	1,85	kN	0,61	0,000723233
S_5	=	1,92	kN	0,65	0,000140031
average value		**1,90**	**kN**	**sum**	**0,002439843**

m_y	=	0,6398068	number of tests	
s_y	=	0,02469738	5	
k_n	=	2,33	α_r	0,800
			β_s	4,700
P_{Rk}	**=**	1,79 kN	k	1,645
			v_y	0,025
P_{Rd}	=	1,43 kN	γ_M	1,250

Fig. 19 Statistical evaluation of the test series

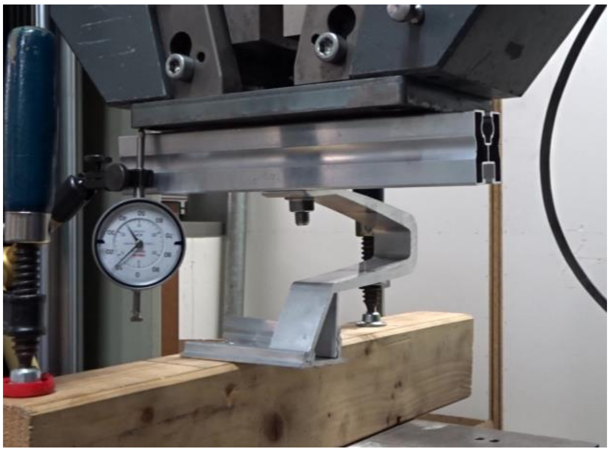

Fig. 20 Test-setup at 1,5 kN

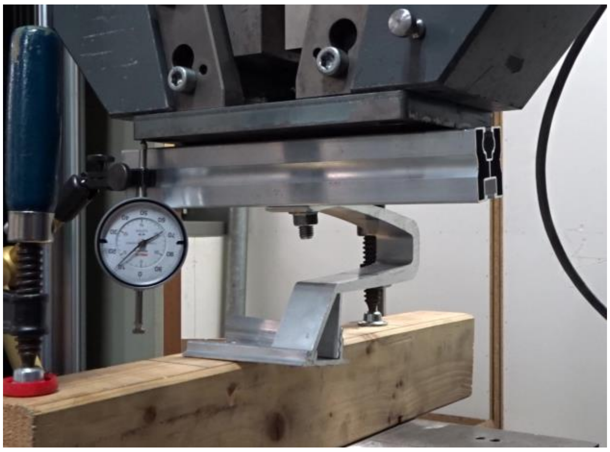

Fig. 21 Test-setup at 1,8 kN

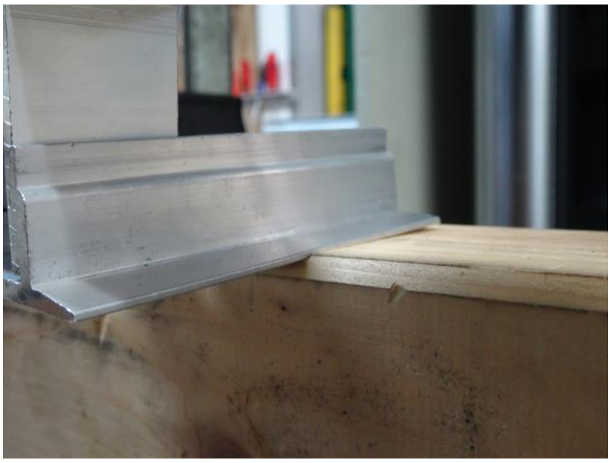

Fig. 22 Bearing surface on wooden beam at 1,9 kN

The measurement records of the pressure tests including the statistical evaluation to deduce characteristic values of the pressure capability and of design values are displayed in Figures 17 and 19. The statistical evaluation is based on EN 1990 Annex Z. The partial safety factor for the resistance side is γ_M = 1.25.

4.2.2 Examination of pressure on steel plate

For the examination of the compressive strength in centric position the roof hook was mounted with a screw on the bottom side on a steel plate fixed in the machine. The tentative test shows that the load bearing capacity does not differ significantly from the eccentric position.

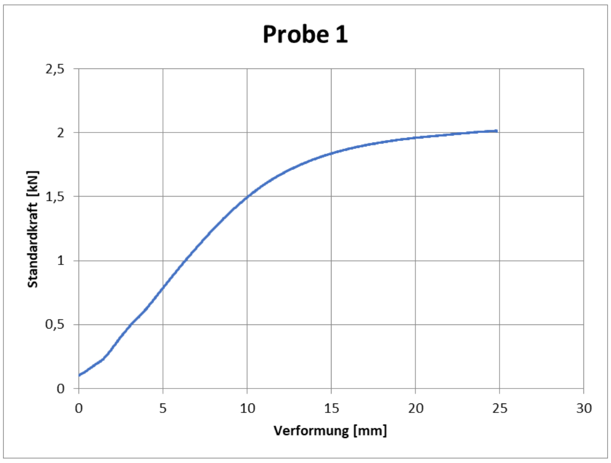

Fig. 23 Measuring records of the tentative tests

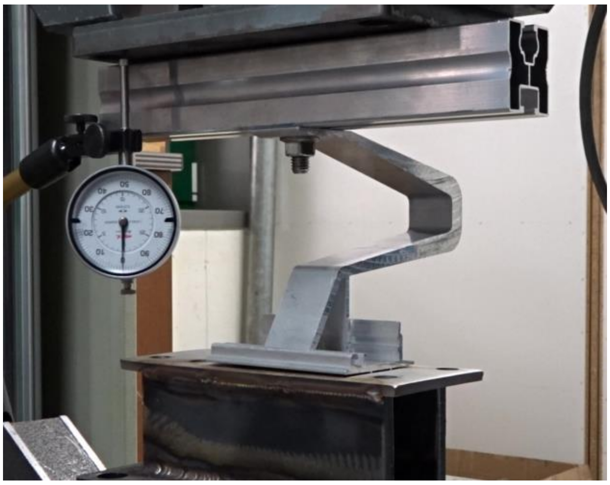

Fig. 24 Assembly at the beginning of the test

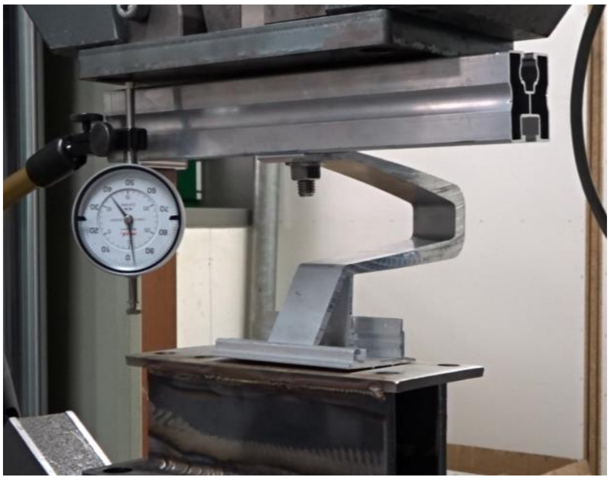

Fig. 25 Test-setup at 1,7 kN

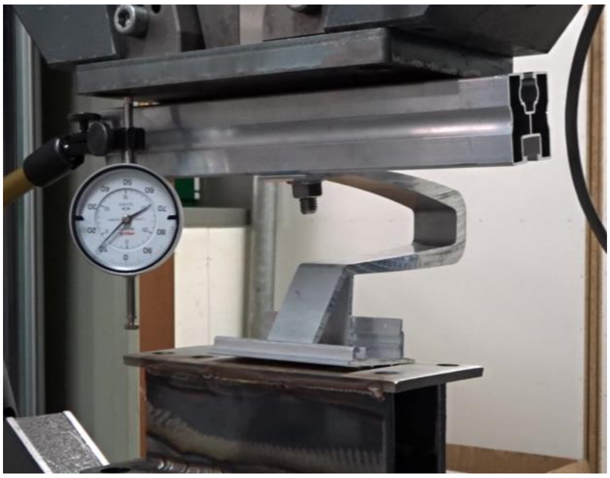

Fig. 26 Test-setup at 2 kN

4.3 Examination of shear strength

The shear strength test was carried out exclusively mounted on a wooden beam. Since the torque caused by the eccentricity acts around the longitudinal axis of the screw, with this type of loading it must be ensured that the rills under the base plate can wedge into the substructure. With increasing load the retaining bracket bends in the direction of the wooden beam.

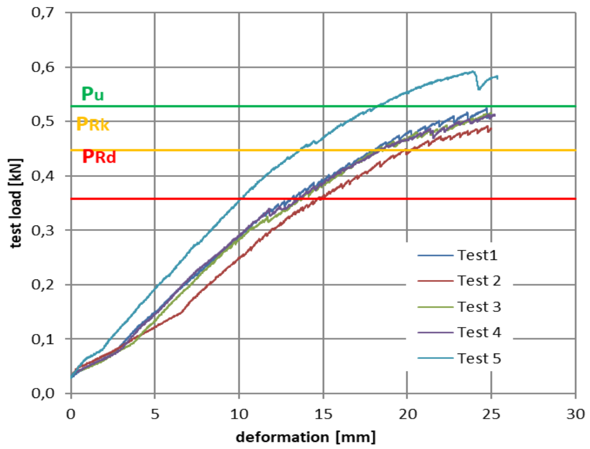

Fig. 27 Measuring records of the shear tests

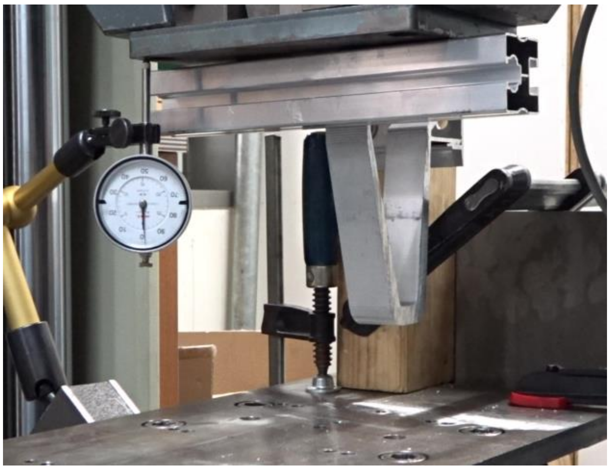

Fig. 28 Assembly at the beginning of the test

statistical evaluation according to DIN EN 1990 annex D

		x_i		$\ln x_i$	
S_1	=	0,52	kN	-0,65	2,14541E-05
S_2	=	0,49	kN	-0,71	0,004596568
S_3	=	0,52	kN	-0,66	0,000429698
S_4	=	0,51	kN	-0,67	0,000614761
S_5	=	0,59	kN	-0,52	0,013913
average value		**0,53**	**kN**	**sum**	**0,019575482**

m_y	=	-0,6413942	number of tests	
s_y	=	0,0699562	5	
k_n	=	2,33	α_r	0,800
			β_s	4,700
P_{Rk}	=	0,45 kN	k	1,645
			v_y	0,070
P_{Rd}	=	0,36 kN	γ_M	1,250

Fig. 29 Statistical evaluation of the test series

Fig. 30 Test-setup at 0,2 kN

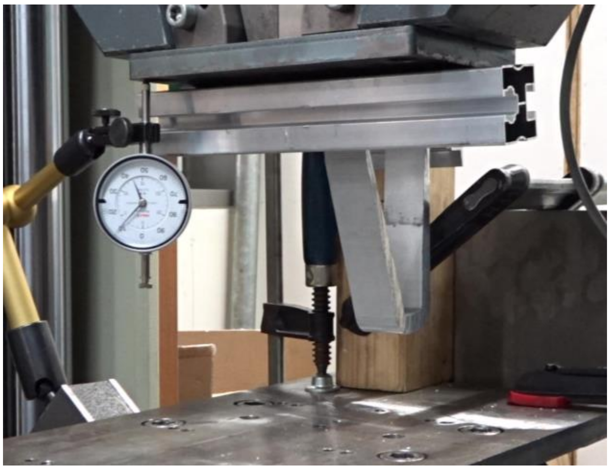

Fig. 31 Test-setup at 0,36 kN

Fig. 32 Test-setup at 0,5 kN

The measurement records of the shear tests including the statistical evaluation to deduce characteristic values of the pressure capability and of design values are displayed in figures 27 and 29. The statistical evaluation is based on EN 1990 Annex Z. The partial safety factor for the resistance side is $\gamma_M = 1.25$.

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5. Summary

The subject of this test report are experimental examinations to determine the load-bearing capacity of roof hooks EcoA of the manufacturer "Schletter Group". The examined construction elements are non-regulated components or construction types of which the load-bearing capacity can only be determined by experimental tests. For the dimensioning of the load bearing capacity the most unfavorable eccentric load position in each test is decisive. The material certificate provides a yield strength of 221 Mpa. To include this post-limit stiffness of 221Mpa/190Mpa = 1.163 in the results, the values from the statistical evaluation are divided by this value. Thus the following load bearing capacities can be derived:

Tensile force (windsuction):	1,45 kN/1,163 = 1,246 kN
Pressure force (dead weight, snow load)):	1,43 kN/1,163 = 1,23 kN
Shear force (dead weight, snow load):	0,36 kN/1,163 = 0,31 kN

In the case of simultaneous occurrence of vertical and horizontal forces, a verification considering a linear interaction is recommended. The testing program consisting of 6 different test series was used primarily to deduce statistically validated design values as a basis for the design verification at the limit state of the bearing capacity.

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