Ensuring Advancement in Sandwich Construction Through Innovation and Exploitation

TEST REPORT

No.: D3.2 – part 2

Tests on the in plane-shear resistance of sandwich panels

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Task: 3.3
Object: Connections of sandwich panels

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1 Preliminary remark

When loaded by in-plane shear forces, sandwich panels have a high shear stiffness. The high in-plane shear stiffness can be used for stabilising single components such as beams and columns by lateral restraint, for transferring of horizontal loads and for stiffening of buildings.

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 this application the utilization of the in-plane shear stiffness for load transfer in the plane of the panel is mandatory.

Because the stiffness of sandwich panels is significantly higher than the stiffness of the connections, the connections are decisive for the stiffness and load-bearing capacity of shear diaphragms made of sandwich panels. Whereas the load-bearing capacity of a connection can be taken from the corresponding technical approvals, no specifications for the stiffness of the connections are available.

Therefore investigations on the stiffness of connections of sandwich panels were performed within the framework of Workpackage 3 of the EASIE project. Connections of sandwich panels and a substructure (Fig. 1) were investigated as well as connections of the longitudinal joints of roof panels, where usually only the external faces of two panels are connected (Fig. 2).

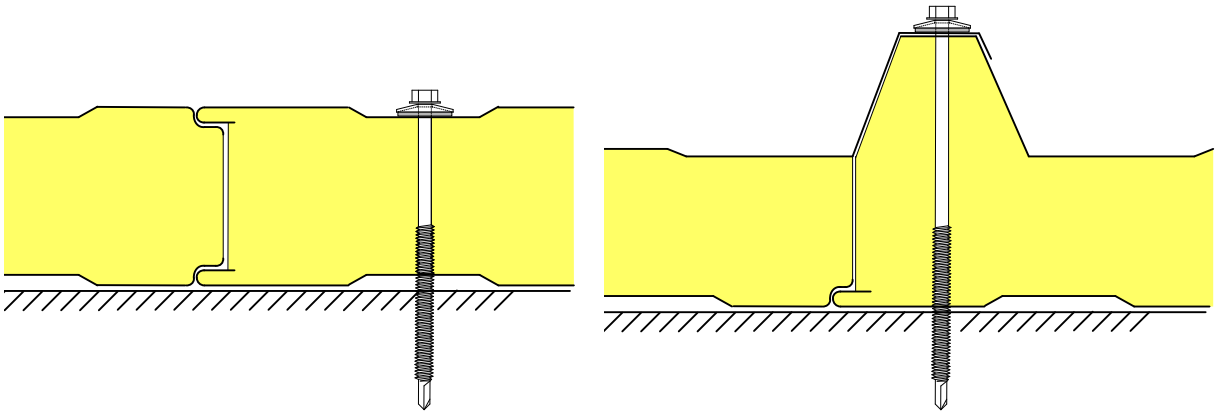


Fig. 1: Connection to the substructure

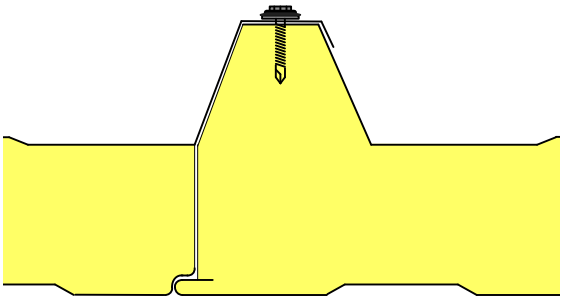


Fig. 2: Connection at the longitudinal joint of roof panels

A similar type of connection can be found in frameless buildings made of sandwich panels - for example at the connection between wall and roof, where angles are fixed to only one face of the panel (Fig. 3). Unlike the connections of longitudinal joints at these connections a relatively thick steel sheet is fixed to the comparatively thin face sheet of the panel. Therefore special screw fasteners for “thick to thin-connections” are used.

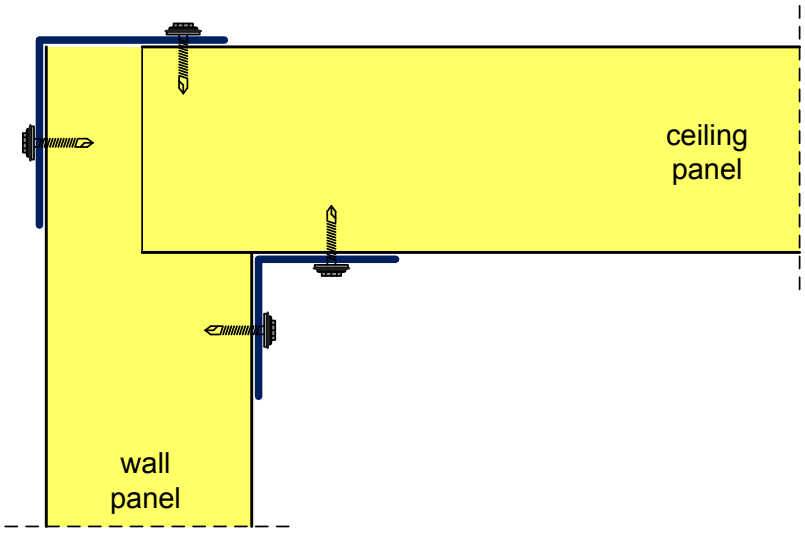


Fig. 3: Corner detail of a frameless building

In deliverable D3.2 – part 2, the results of the experimental tests on connections of sandwich panels are presented. The evaluation of the test results can be found in deliverable D3.3. Deliverable D3.3 is also dealing with the design of diaphragms made of sandwich panels.

2 Object of testing

Tests with different types of self-drilling and self tapping screws were performed. A compilation of the screw fasteners used for the tests and the usual application range of the fasteners are given in Tab. 1. In Tab. 2 the nominal dimensions of the fasteners are given. Drawings of the fasteners are presented in annex 1. For each type of fastener the thread, the shaft and the pin were measured. The measured dimensions are also given in annex 1.

fastener	application range
JT3-6-5,5x130	self-drilling screw fixing of sandwich panels to a steel substructure
JT3-6-5,5x170	
JT3-12-5,5x138	
JT3-12-5,5x178	
JZ3-6,3x150	self-tapping screw fixing of sandwich panels to a steel substructure
JZ3-6,3x175	
JZ3-8,0x150	
SL2-S-4,8x22	self-drilling screw connection of longitudinal joints
SL2-S-5,5x27	
SL2-S-L12-6,3x28	
JT3-2-6,0x25	self-drilling screw fixing of a thick to a thin steel sheet
SL3/2-5-S-SV16-6,0x27	

Tab. 1: Application range of tested fasteners

fastener	external diameter	core diame-ter	thread pitch	pin diameter	length of pin	diameter of washer
JT3-6-5,5x130	5,46	4,17	1,8	4,5	9	22
JT3-6-5,5x170	5,46	4,17	1,8	4,5	9	16
JT3-12-5,5x138	5,46	4,17	1,8	5,0	16	16
JT3-12-5,5x178	5,46	4,17	1,8	5,0	16	16
JZ3-6,3x150	6,25	4,88	1,8	-	-	16
JZ3-6,3x175	6,25	4,88	1,8	-	-	16
JZ3-8,0x150	8,0	6,2	2,1	-	-	22
SL2-S-4,8x22	4,8	3,5	1,59	3,2	-	14
SL2-S-5,5x27	5,5	3,4	2,2	2,8	-	14
SL2-S-L12-6,3x28	6,3	4,5	1,95	3,9	10	14
JT3-2-6,0x25	6,0	-	2,0	3,6	-	-
SL3/2-5-S-SV16-6,0x27	6,0	-	1,81	3,6	7,5	13x16

Tab. 2: Nominal dimensions of tested fasteners [mm]

In the tests different types of sandwich panels were used. The sandwich panels used for the tests are given in Tab. 3.

No.	core material	thickness of core	face material	thickness of face	profiling of faces
A	PU	100 mm	steel	0,50 mm	lightly profiled
B	PU	100 mm	steel	0,75 mm	lightly profiled
C	EPS	100 mm	steel	0,60 mm	flat

Tab. 3: Tested types of sandwich panels

3 Tests on fixings of sandwich panels to a substructure

3.1 Preliminary remarks

The stiffness of a connection depends on the following parts:

- stiffness of the internal face sheet (hole elongation)
- stiffness of the external face sheet (hole elongation)
- bending stiffness of the screw fastener
- stiffness of clamping of the fastener into the substructure
- stiffness of clamping of the head on the external face

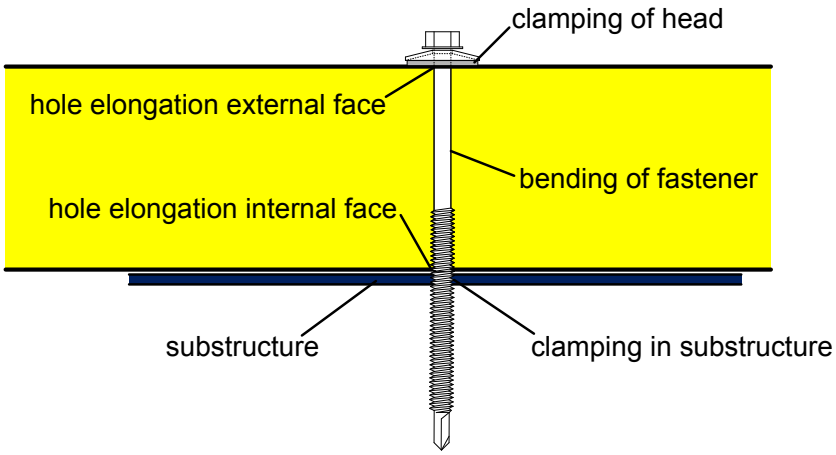


Fig. 4: Stiffness of connections

To determine each of the above stiffness's the following tests were performed

- Hole elongation tests
- Bending tests (stiffness of the clamping in the substructure)
- Tests to determine the effect of clamping of the head
- "Full-scale" tests on connections for verification of the design model

3.2 Hole elongation tests

The test set-up for the hole elongation tests is given in Fig. 5 and Fig. 6.

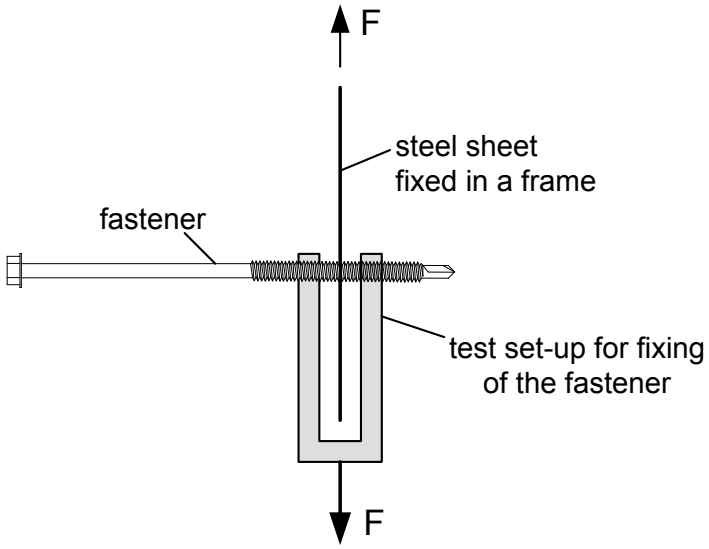


Fig. 5: Test set-up for hole elongation tests

Fig. 6: Test set-up for hole elongation tests

The fastener was set into the steel sheet. The steel sheet was fixed in a frame and the fastener was also fixed in the test set-up. The specimen was loaded stepwise with an increase of displacement of approximately 0,5 mm in each load step, until a displacement of 3,0 mm was achieved. After each load step the specimen was unloaded to zero.

During the tests the thickness of the steel sheet and the nominal diameter of the fastener were varied. Tab. 4 and Tab. 5 show a compilation of the hole elongation tests. The measured dimensions of the elongated holes are also given in Tab. 4 and Tab. 5. The load-displacement-relationships of the hole elongation tests are shown in annex 2.

No.	thickness of steel sheet [mm]	fastener	pre-drilling diameter [mm]	dimensions of elongated hole [mm]	
				lengthwise	crosswise
0,40-5,5-1	0,40	JT3-6-5,5x170	-	7,91	5,00
0,40-5,5-2				7,46	4,94
0,40-5,5-3				7,76	4,60
0,40-5,5-4				7,66	4,43
0,40-5,5-5				8,16	4,73
0,40-6,3-1		JZ3-6,3x175	5,0	8,26	5,14
0,40-6,3-2				8,01	4,96
0,40-6,3-3				8,07	4,94
0,40-6,3-4				8,13	4,94
0,40-6,3-5				8,23	4,96
0,40-6,3-6				7,87	5,26
0,40-8,0-1		JZ3-8,0x150	6,8	9,49	6,97
0,40-8,0-2				9,83	6,90
0,40-8,0-3				10,39	7,07
0,50-5,5-1	0,50	JT3-6-5,5x170	-	7,46	4,52
0,50-5,5-2				7,85	4,20
0,50-5,5-3				7,88	4,40
0,50-5,5-4				8,72	4,35
0,50-5,5-5				7,06	4,13
0,50-6,3-1		JZ3-6,3x175	5,0	7,39	5,23
0,50-6,3-2				8,02	5,19
0,50-6,3-3				7,81	4,98
0,50-6,3-4				8,59	4,99
0,50-6,3-5				7,99	5,03
0,50-8,0-1		JZ3-8,0x150	6,8	9,71	7,12
0,50-8,0-2				10,20	6,82
0,50-8,0-3				9,49	6,63
0,50-8,0-4				9,80	6,78
0,50-8,0-5				9,42	6,97

Tab. 4: Compilation of hole elongation tests

No.	thickness of steel sheet [mm]	fastener	pre-drilling diameter [mm]	dimensions of elongated hole [mm]	
				lengthwise	crosswise
0,75-5,5-1	0,75	JT3-6-5,5x170	-	7,80	4,36
0,75-5,5-2				8,24	4,13
0,75-5,5-3				8,86	4,08
0,75-5,5-4				6,80	4,43
0,75-5,5-5				7,71	4,44
0,75-6,3-1		JZ3-6,3x175	5,0	8,00	4,90
0,75-6,3-2				8,16	4,99
0,75-6,3-3				7,35	5,11
0,75-6,3-4				8,08	5,08
0,75-6,3-5				7,47	5,32
0,75-8,0-1		JZ3-8,0x150	6,8	9,87	6,96
0,75-8,0-2				10,46	6,86
0,75-8,0-3				10,03	7,14
0,75-8,0-4				10,31	6,87
0,75-8,0-5				9,19	6,65
1,00-5,5-1	1,00	JT3-6-5,5x170	-	6,98	4,40
1,00-5,5-2				7,69	4,02
1,00-5,5-3				7,12	4,18
1,00-5,5-4				6,61	4,55
1,00-5,5-5				6,82	4,15
1,00-6,3-1		JZ3-6,3x175	5,0	7,76	4,81
1,00-6,3-2				7,56	4,67
1,00-6,3-3				8,12	4,74
1,00-6,3-4				8,10	4,65
1,00-6,3-5				7,23	4,70
1,00-8,0-1		JZ3-8,0x150	6,8	8,53	6,74
1,00-8,0-2				9,66	6,47
1,00-8,0-3				8,86	6,92
1,00-8,0-4				7,80	6,62
1,00-8,0-5				8,13	6,75

Tab. 5: Compilation of hole elongation tests - continuation

3.3 Bending tests

The test set-up for the bending tests is given in Fig. 7 and Fig. 8.

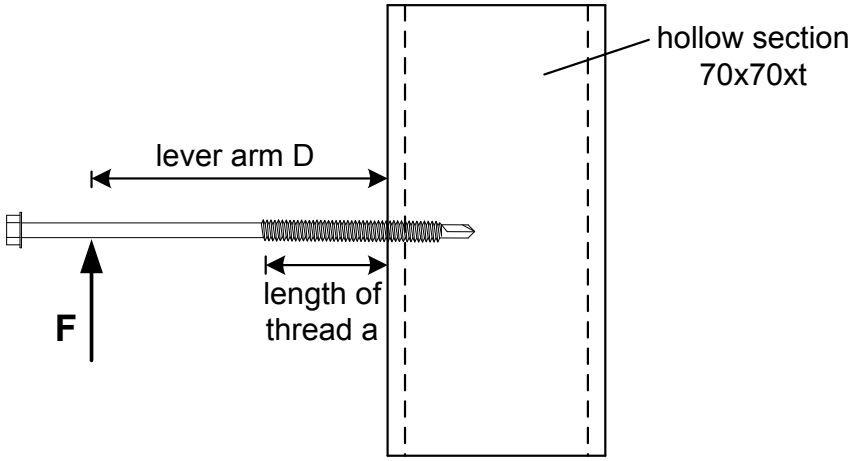


Fig. 7: Test set-up for bending tests

Fig. 8: Test set-up for bending tests

The screw fastener was mounted into a hollow section. For each specimen the length a of the thread was measured with reference to the surface of the hollow section (Tab. 6, Tab. 7). The fastener was loaded in the manner of a cantilever beam. At the point of load application the fastener could freely rotate. The load was increased until the non-linear part of the load-

displacement-relationship was achieved. At the end of the tests the fastener was unloaded to zero.

During the tests the wall thickness of the hollow section, the nominal diameter of the fastener and the lever arm D were varied. Tab. 6 and Tab. 7 show a compilation of the bending tests. The load-displacement-diagrams of the tests are shown in annex 3.

No.	thickness of hollow section [mm]	fastener	pre-drilling diameter [mm]	lever arm D [mm]	length of thread a [mm]
2,0-5,5-40-1	2,0	JT3-6-5,5x170	-	40	14
2,0-5,5-40-2				40	13
2,0-5,5-40-3				42	17
2,0-5,5-90-1				90	15
2,0-5,5-90-2				90	18
2,0-5,5-90-3				90	18
2,0-5,5-125-1				125	18
2,0-5,5-125-2				125	19
2,0-5,5-125-3				125	17
3,0-6,3-40-1	3,0	JZ3-6,3x175	5,3	40	27
3,0-6,3-40-2				40	27
3,0-6,3-40-3				40	26
3,0-6,3-90-1				90	28
3,0-6,3-90-2				90	27
3,0-6,3-90-3				90	26
3,0-6,3-125-1				125	26
3,0-6,3-125-2				125	26
3,0-6,3-125-3				125	26
4,0-8,0-40-1	4,0	JZ3-8,0x150	6,8	40	27
4,0-8,0-40-2				40	28
4,0-8,0-40-3				40	29
4,0-8,0-80-1				80	25
4,0-8,0-80-2				80	29
4,0-8,0-80-3				80	27
4,0-8,0-110-1				110	29
4,0-8,0-110-2				110	29
4,0-8,0-110-3				100	27

Tab. 6: Compilation of bending tests

No.	thickness of hollow section [mm]	fastener	pre-drilling diameter [mm]	lever arm D [mm]	length of thread a [mm]
5,0-5,5-40-1	5,0	JT3-12-5,5x178	-	40	16
5,0-5,5-40-2				40	13
5,0-5,5-40-3				40	17
5,0-5,5-90-1				90	17
5,0-5,5-90-2				90	16
5,0-5,5-90-3				90	15
5,0-5,5-120-1				120	16
5,0-5,5-120-2				120	17
5,0-5,5-120-3				120	16
6,0-6,3-40-1	6,0	JZ3-6,3x175	5,5	40	28
6,0-6,3-40-2				40	27
6,0-6,3-40-3				40	27
6,0-6,3-80-1				80	26
6,0-6,3-80-2				80	27
6,0-6,3-80-3				80	27
6,0-6,3-120-1				120	27
6,0-6,3-120-2				121	27
6,0-6,3-120-3				120	27
8,0-8,0-40-1	8,0	JZ3-8,0x150	7,2	41	28
8,0-8,0-40-2				41	26
8,0-8,0-40-3				39	32
8,0-8,0-80-1				80	28
8,0-8,0-80-2				80	26
8,0-8,0-80-3				80	34
8,0-8,0-110-1				112	35
8,0-8,0-110-2				112	38
8,0-8,0-110-3				110	35

Tab. 7: Compilation of bending tests - continuation

3.4 Tests on clamping of the head

For investigating the effect of the clamping of the head at the external face full-scale tests on connections of sandwich panels and a substructure were performed. For these tests two kinds of specimens were used. In the first tests series (series a) the connections were executed in the usual way. In the second test series (series b) the panels were screwed to the substructure developing a gap between the external face of the panel and the washer of the fastener

(Fig. 9). In the connections of test series b the head of the fastener can freely rotate and so there is not any clamping of the head.

Fig. 9: Specimens with and without clamping of the head

A test set up according to the ECCS-recommendations [1], [2] was used. In each test two connections were tested. The test set up is given in Fig. 10 and Fig. 11.

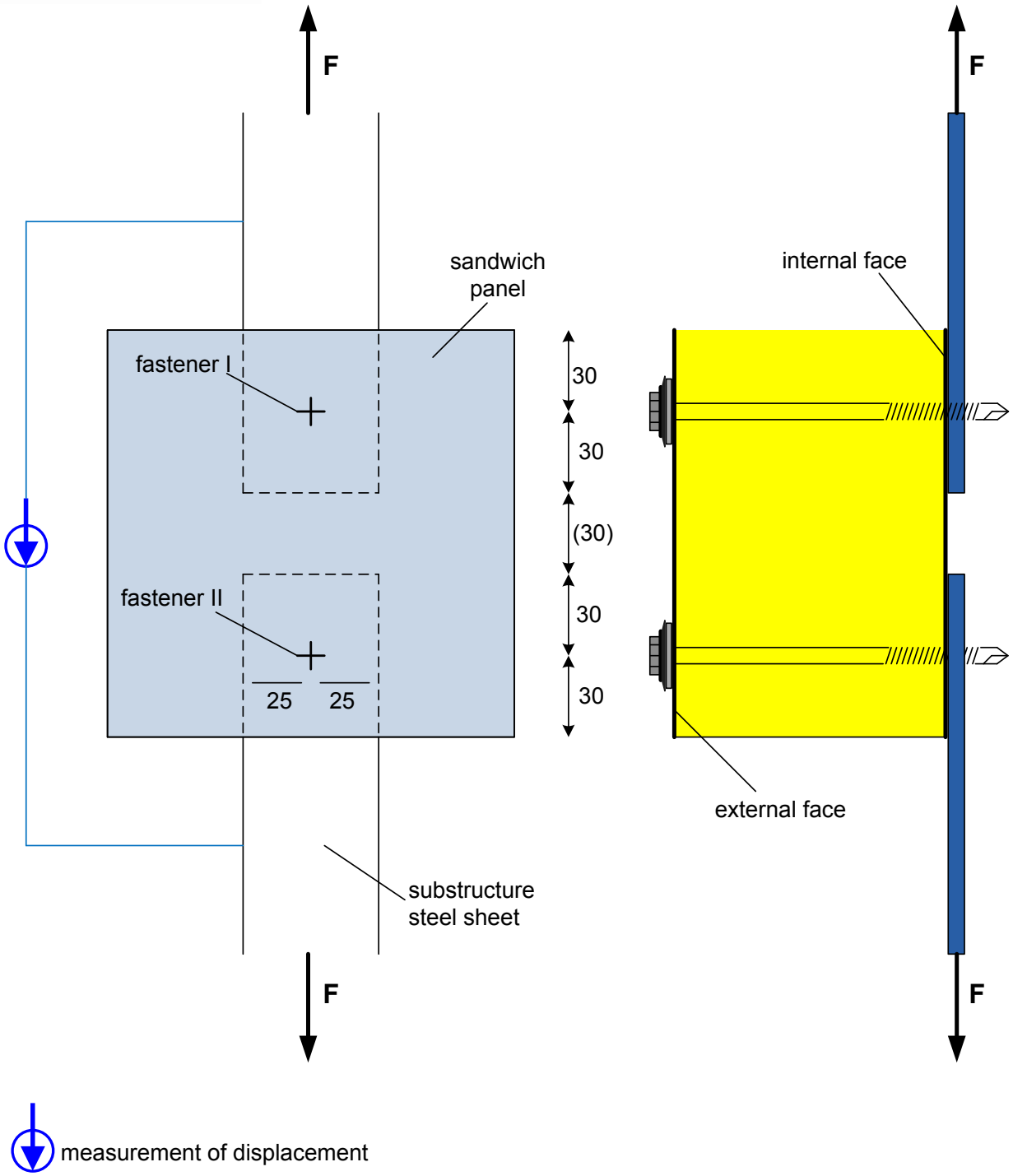


Fig. 10: Test set-up for full scale tests

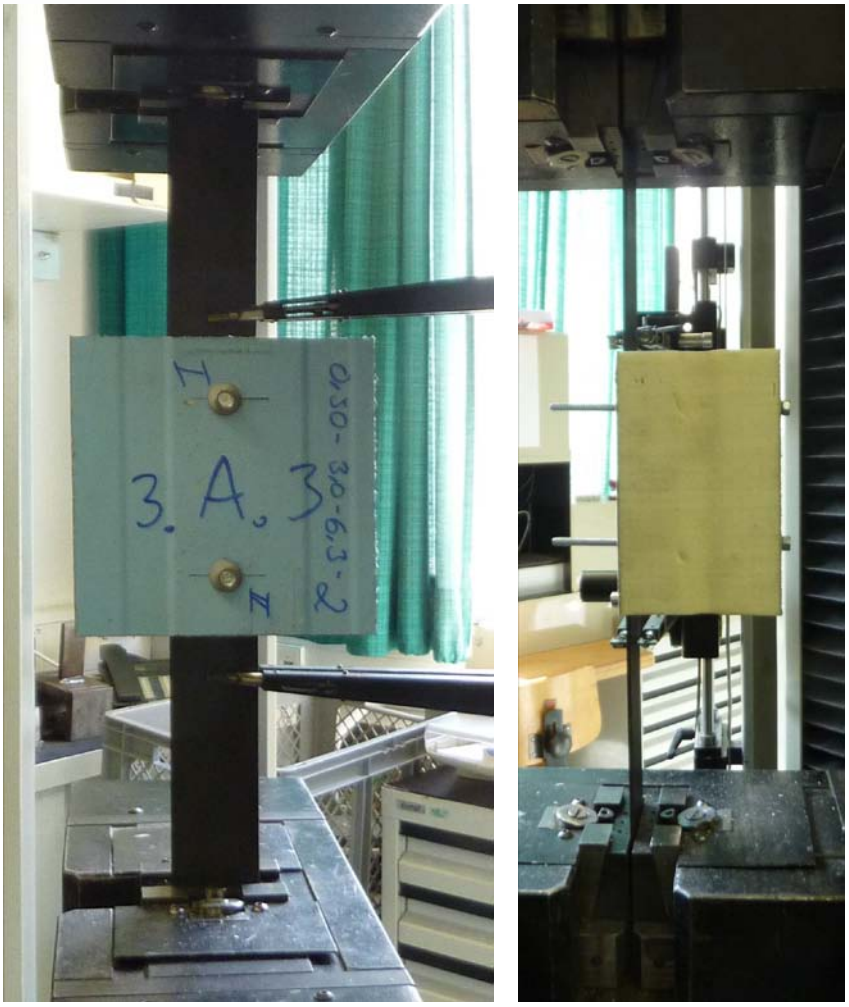


Fig. 11: Test set-up for full scale tests

Tab. 8 shows a compilation of the tests for investigating the clamping of the head.

No.	fastener	pre-drilling diameter [mm]	type of panel / thickness of faces [mm]	thickness of substructure [mm]	clamping of head
0,60-2,0-5,5-a	JT3-6-5,5x130	-	C / 0,60	2,0	yes
0,60-3,0-6,3-a	JZ3-6,3x150	5,3	C / 0,60	3,0	yes
0,75-6,0-6,3-a	JZ3-6,3x150	5,5	B / 0,75	6,0	yes
0,60-2,0-5,5-b	JT3-6-5,5x130	-	C / 0,60	2,0	no
0,60-3,0-6,3-b	JZ3-6,3x150	5,3	C / 0,60	3,0	no
0,75-6,0-6,3-b	JZ3-6,3x150	5,5	B / 0,75	6,0	no

Tab. 8: Compilation of tests on clamping of the head

The specimens were loaded with a displacement-rate of 2 mm/min until a displacement of approximately 15,0 mm was reached. The load-displacement-diagrams of the tests are shown

in annex 4. After the tests the inclination of the fasteners was measured. The specimens were demounted and the dimensions of the elongated holes were measured (Tab. 9 and Tab. 10).

No.	inclination of fastener [°]	dimensions of elongated hole [mm]					
		internal face		external face		substructure	
		length-wise	cross-wise	length-wise	cross-wise	length-wise	cross-wise
0,60-2,0-5,5-a-1-I	4,0	14,18	4,68	4,61	4,58	4,61	4,54
0,60-2,0-5,5-a-1-II	2,5	8,52	4,63	4,70	4,62	4,56	4,53
0,60-2,0-5,5-a-2-I	5,5	13,04	4,68	4,56	4,69	4,58	4,54
0,60-2,0-5,5-a-2-II	4,5	9,67	4,62	4,65	4,64	4,59	4,56
0,60-2,0-5,5-a-3-I	4,0	11,13	4,61	4,66	4,57	4,54	4,46
0,60-2,0-5,5-a-3-II	5,5	11,51	4,91	4,70	4,51	4,58	4,73
0,60-3,0-6,3-a-1-I	2,0	7,06	5,87	5,22	5,24	5,09	5,03
0,60-3,0-6,3-a-1-II	5,0	16,32	4,77	5,23	5,27	5,11	5,30
0,60-3,0-6,3-a-2-I	1,5	7,68	5,15	5,22	5,18	5,22	5,04
0,60-3,0-6,3-a-2-II	5,0	16,26	5,08	5,27	5,18	5,10	5,14
0,60-3,0-6,3-a-3-I	3,0	7,23	5,16	5,20	5,23	5,03	5,01
0,60-3,0-6,3-a-3-II	5,0	16,90	5,23	5,17	5,20	5,04	5,02
0,75-6,0-6,3-a-1-I	1,5	8,66	5,09	5,39	5,23	5,39	5,34
0,75-6,0-6,3-a-1-II	1,0	15,27	5,44	5,34	5,26	5,35	5,25
0,75-6,0-6,3-a-2-I	2,0	9,70	4,81	5,19	5,42	5,71	5,19
0,75-6,0-6,3-a-2-II	2,0	15,72	4,87	5,27	5,13	5,30	5,25
0,75-6,0-6,3-a-3-I	2,0	7,07	4,84	5,22	5,24	5,11	5,18
0,75-6,0-6,3-a-3-II	2,0	17,13	5,10	5,41	5,22	5,22	5,41
0,60-2,0-5,5-b-1-I	4,0	5,72	4,57	4,62	4,55	4,55	4,50
0,60-2,0-5,5-b-1-II	7,0	16,78	4,57	4,58	4,67	4,49	4,59
0,60-2,0-5,5-b-2-I	1,5	6,18	4,77	4,68	4,61	4,51	4,42
0,60-2,0-5,5-b-2-II	7,5	16,39	4,95	4,70	4,61	4,57	4,51
0,60-2,0-5,5-b-3-I	2,5	11,91	4,83	4,64	4,55	4,62	4,55
0,60-2,0-5,5-b-3-II	4,0	10,90	4,85	4,57	4,59	4,54	4,51
0,60-3,0-6,3-b-1-I	2,0	6,87	5,10	5,19	5,17	5,26	5,00
0,60-3,0-6,3-b-1-II	4,5	17,07	4,64	5,23	5,25	5,06	5,07
0,60-3,0-6,3-b-2-I	7,0	15,63	5,22	5,22	5,22	5,05	5,09
0,60-3,0-6,3-b-2-II	2,0	7,22	5,13	5,11	5,16	4,95	5,02
0,60-3,0-6,3-b-3-I	6,0	17,14	5,15	5,21	5,20	5,00	4,84
0,60-3,0-6,3-b-3-II	1,5	6,74	5,08	5,18	5,22	5,12	5,05

Tab. 9: Measured dimensions

No.	inclination of fastener [°]	dimensions of elongated hole [mm]					
		internal face		external face		substructure	
		length-wise	cross-wise	length-wise	cross-wise	length-wise	cross-wise
0,75-6,0-6,3-b-1-I	2,0	7,24	5,18	5,23	5,15	5,35	5,36
0,75-6,0-6,3-b-1-II	4,0	17,01	5,02	5,41	5,32	5,31	5,17
0,75-6,0-6,3-b-2-I	6,0	16,83	4,96	5,23	5,30	5,25	5,36
0,75-6,0-6,3-b-2-II	1,0	7,19	5,11	5,34	5,17	5,32	5,23
0,75-6,0-6,3-b-3-I	3,0	16,07	5,29	5,25	5,22	5,29	5,35
0,75-6,0-6,3-b-3-II	2,0	8,40	5,10	5,18	5,39	5,34	5,31

Tab. 10: Measured dimensions - continuation

3.5 Full scale tests

For verification of the design model some full-scale tests were performed. A test set up according to the ECCS-recommendations [1], [2] was used. In each test two connections were tested. The test set up is given in Fig. 10 and Fig. 11.
During the tests the thickness of the substructure and of the face sheets as well as the nominal diameter of the fasteners were varied. Tab. 11 shows a compilation of the full-scale tests.

No.	fastener	pre-drilling diameter [mm]	thickness of sub-structure [mm]	type of panel / thickness of faces [mm]
0,50-2,0-5,5	JT3-6-5,5x130	-	2,0	A / 0,50
0,50-3,0-6,3	JZ3-6,3x150	5,3	3,0	A / 0,50
0,50-4,0-8,0	JZ3-8,0x150	6,8	4,0	A / 0,50
0,60-2,0-5,5	JT3-6-5,5x130	-	2,0	C / 0,60
0,60-3,0-6,3	JZ3-6,3x150	5,3	3,0	C / 0,60
0,60-4,0-8,0	JZ3-8,0x150	6,8	4,0	C / 0,60
0,60-5,0-5,5	JT3-12-5,5x138	-	5,0	C / 0,60
0,60-6,0-6,3	JZ3-6,3x150	5,5	6,0	C / 0,60
0,60-8,0-8,0	JZ3-8,0x150	7,2	8,0	C / 0,60
0,75-5,0-5,5	JT3-12-5,5x138	-	5,0	B / 0,75
0,75-6,0-6,3	JZ3-6,3x150	5,5	6,0	B / 0,75
0,75-8,0-8,0	JZ3-8,0x150	7,2	8,0	B / 0,75

Tab. 11: Compilation of full-scale tests

The specimens were loaded with a displacement-rate of 2 mm/min until a displacement of approximately 6.0 mm was reached. After the test the specimen was unloaded to zero and the

inclination of the fasteners was measured. The specimens were demounted and the dimensions of the elongated holes were measured (Tab. 12 to Tab. 14). The load-displacement-diagrams of the full-scale tests are shown in annex 5.

No.	inclination of fastener [°]	dimensions of elongated hole [mm]					
		internal face		external face		substructure	
		length-wise	cross-wise	length-wise	cross-wise	length-wise	cross-wise
0,50-2,0-5,5-1-I	2,0	7,74	4,70	4,61	4,61	4,51	4,50
0,50-2,0-5,5-1-II	2,0	6,19	4,78	4,68	4,56	4,56	4,52
0,50-2,0-5,5-2-I	2,0	7,93	4,69	4,58	4,52	4,67	4,52
0,50-2,0-5,5-2-II	3,0	5,68	4,74	4,60	4,58	4,56	4,52
0,50-2,0-5,5-3-I	1,0	6,41	4,82	4,72	4,63	4,53	4,50
0,50-2,0-5,5-3-II	2,5	8,48	4,79	4,70	4,69	4,48	5,54
0,50-3,0-6,3-1-I	1,0	6,96	5,47	5,29	5,31	4,91	5,03
0,50-3,0-6,3-1-II	0,5	9,14	5,33	5,00	5,37	4,97	4,99
0,50-3,0-6,3-2-I	1,5	7,42	5,55	5,38	5,45	5,08	5,14
0,50-3,0-6,3-2-II	0,5	8,62	5,56	5,48	5,50	5,10	5,12
0,50-3,0-6,3-3-I	0,0	8,30	5,32	5,33	5,34	5,02	5,10
0,50-3,0-6,3-3-II	1,0	7,40	5,46	5,33	5,35	5,14	5,11
0,50-4,0-8,0-1-I	0,5	8,27	7,13	6,98	6,86	6,54	6,62
0,50-4,0-8,0-1-II	0,5	10,30	6,94	6,81	6,99	6,75	6,48
0,50-4,0-8,0-2-I	1,0	8,25	6,93	7,01	7,00	6,64	6,96
0,50-4,0-8,0-2-II	1,0	10,80	7,06	7,03	7,05	6,77	6,72
0,50-4,0-8,0-3-I	1,0	8,55	7,12	7,12	7,05	6,70	6,55
0,50-4,0-8,0-3-II	0,0	10,29	7,14	6,75	6,69	6,52	6,55
0,60-2,0-5,5-1-I	3,0	6,44	4,79	4,71	4,50	4,53	4,51
0,60-2,0-5,5-1-II	3,0	8,43	5,05	4,68	4,52	4,54	4,55
0,60-2,0-5,5-2-I	2,0	8,00	4,53	4,64	4,72	4,48	5,52
0,60-2,0-5,5-2-II	2,0	6,31	4,64	4,55	4,54	4,57	4,52
0,60-2,0-5,5-3-I	1,0	8,50	4,86	4,68	4,54	4,51	4,50
0,60-2,0-5,5-3-II	2,0	6,22	5,06	4,56	4,62	4,49	4,48
0,60-3,0-6,3-1-I	1,0	7,05	5,31	5,44	5,51	5,16	5,11
0,60-3,0-6,3-1-II	1,0	8,75	5,39	5,30	5,31	5,03	5,97
0,60-3,0-6,3-2-I	0,5	10,16	5,33	5,30	5,39	4,96	5,16
0,60-3,0-6,3-2-II	1,0	6,20	5,43	5,35	5,30	5,06	5,11
0,60-3,0-6,3-3-I	1,0	6,93	5,53	5,23	5,30	5,03	4,97
0,60-3,0-6,3-3-II	0,5	8,76	5,46	5,31	5,34	5,13	5,06

Tab. 12: Measured dimensions

No.	inclination of fastener [°]	dimensions of elongated hole [mm]					
		internal face		external face		substructure	
		length-wise	cross-wise	length-wise	cross-wise	length-wise	cross-wise
0,60-4,0-8,0-1-I	0,5	7,79	7,06	6,88	6,94	6,56	6,80
0,60-4,0-8,0-1-II	1,0	11,34	6,98	6,87	7,02	6,62	6,62
0,60-4,0-8,0-2-I	0,5	9,53	7,09	6,94	7,06	6,98	6,88
0,60-4,0-8,0-2-II	1,0	9,69	7,00	6,98	7,01	6,60	6,58
0,60-4,0-8,0-3-I	2,0	7,77	7,10	6,93	6,96	6,60	6,60
0,60-4,0-8,0-3-II	1,0	11,14	7,23	6,94	6,98	6,67	6,58
0,60-5,0-5,5-1-I	2,0	8,49	5,06	4,93	5,04	4,99	5,01
0,60-5,0-5,5-1-II	1,0	7,02	5,18	5,12	5,07	5,03	5,02
0,60-5,0-5,5-2-I	0,5	6,64	5,12	5,03	4,95	5,15	4,98
0,60-5,0-5,5-2-II	1,0	7,75	5,11	5,07	5,11	5,02	5,02
0,60-5,0-5,5-3-I	1,0	8,04	5,06	5,04	4,98	5,01	4,90
0,60-5,0-5,5-3-II	0,,5	6,98	5,08	5,11	4,96	5,07	5,05
0,60-6,0-6,3-1-I	1,0	7,87	5,47	5,63	5,47	5,15	5,07
0,60-6,0-6,3-1-II	0,5	7,56	5,62	5,53	5,49	5,16	5,14
0,60-6,0-6,3-2-I	0,5	7,69	5,51	5,50	5,54	4,99	5,19
0,60-6,0-6,3-2-II	0,5	7,65	5,54	5,52	5,55	5,26	5,23
0,60-6,0-6,3-3-I	0,5	6,29	5,52	5,59	5,51	5,22	5,24
0,60-6,0-6,3-3-II	0,5	9,46	5,46	5,51	5,46	5,11	5,06
0,60-8,0-8,0-1-I	0,0	8,61	7,11	7,19	7,20	7,18	6,85
0,60-8,0-8,0-1-II	2,0	9,43	7,17	7,18	7,20	6,79	6,90
0,60-8,0-8,0-2-I	0,5	10,16	7,16	7,23	7,16	6,80	6,75
0,60-8,0-8,0-2-II	0,0	8,52	7,04	7,18	7,19	6,82	6,78
0,60-8,0-8,0-3-I	0,0	9,36	7,21	7,23	7,22	6,82	6,76
0,60-8,0-8,0-3-II	1,0	9,18	7,23	7,23	7,20	6,77	6,75
0,75-5,0-5,5-1-I	1,0	7,06	5,08	5,02	5,19	4,94	4,89
0,75-5,0-5,5-1-II	1,5	7,22	5,04	5,01	5,01	4,98	4,96
0,75-5,0-5,5-2-I	2,0	7,16	5,03	5,09	5,13	4,98	4,89
0,75-5,0-5,5-2-II	1,0	7,11	5,02	5,10	4,98	4,97	4,90
0,75-5,0-5,5-3-I	1,5	7,93	5,11	5,07	5,07	5,01	4,99
0,75-5,0-5,5-3-II	1,0	7,03	5,11	5,04	5,14	5,03	4,99
0,75-6,0-6,3-1-I	1,0	7,28	5,56	5,60	5,44	5,21	5,21
0,75-6,0-6,3-1-II	0,5	8,39	5,22	5,50	5,44	5,19	5,16
0,75-6,0-6,3-2-I	0,5	8,40	5,51	5,64	5,61	5,26	5,07
0,75-6,0-6,3-2-II	1,0	7,44	5,60	5,44	5,59	5,23	5,25

Tab. 13: Measured dimensions – continuation

No.	inclination of fastener [°]	dimensions of elongated hole [mm]					
		internal face		external face		substructure	
		length-wise	cross-wise	length-wise	cross-wise	length-wise	cross-wise
0,75-6,0-6,3-3-I	0,5	7,64	5,43	5,72	5,66	5,20	5,14
0,75-6,0-6,3-3-II	1,0	7,66	5,72	5,39	5,48	5,21	5,32
0,75-8,0-8,0-1-I	1,0	8,10	7,29	7,24	7,22	7,00	6,89
0,75-8,0-8,0-1-II	0,5	10,65	7,22	7,23	7,18	6,97	6,86
0,75-8,0-8,0-2-I	1,0	9,30	7,24	7,24	7,09	7,02	6,85
0,75-8,0-8,0-2-II	1,0	10,15	7,12	7,15	7,23	6,91	7,06
0,75-8,0-8,0-3-I	1,0	9,25	7,20	7,18	7,17	6,80	6,85
0,75-8,0-8,0-3-II	1,5	9,25	7,19	7,12	7,18	6,84	6,73

Tab. 14: Measured dimensions - continuation

4 Tests on connections of longitudinal joints

In addition to the tests on connections of sandwich panels to a substructure also tests on connections of longitudinal joints were performed. Because in building practice usually a sealing tape is mounted between the connected face sheets, also tests with a sealing tape were performed (Fig. 12). A sealing tape LS-15/2-3 was used.

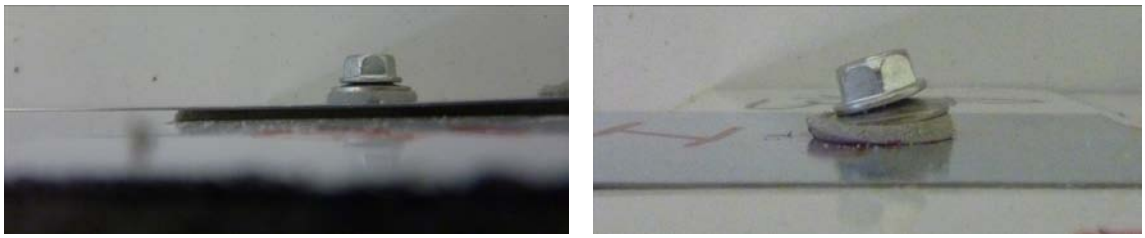


Fig. 12: Connection with and without sealing tape

In the tests a test set up according to the ECCS-recommendations [1], [2] was used. In each test two connections were tested. The test set up is given in Fig. 13 and Fig. 14.

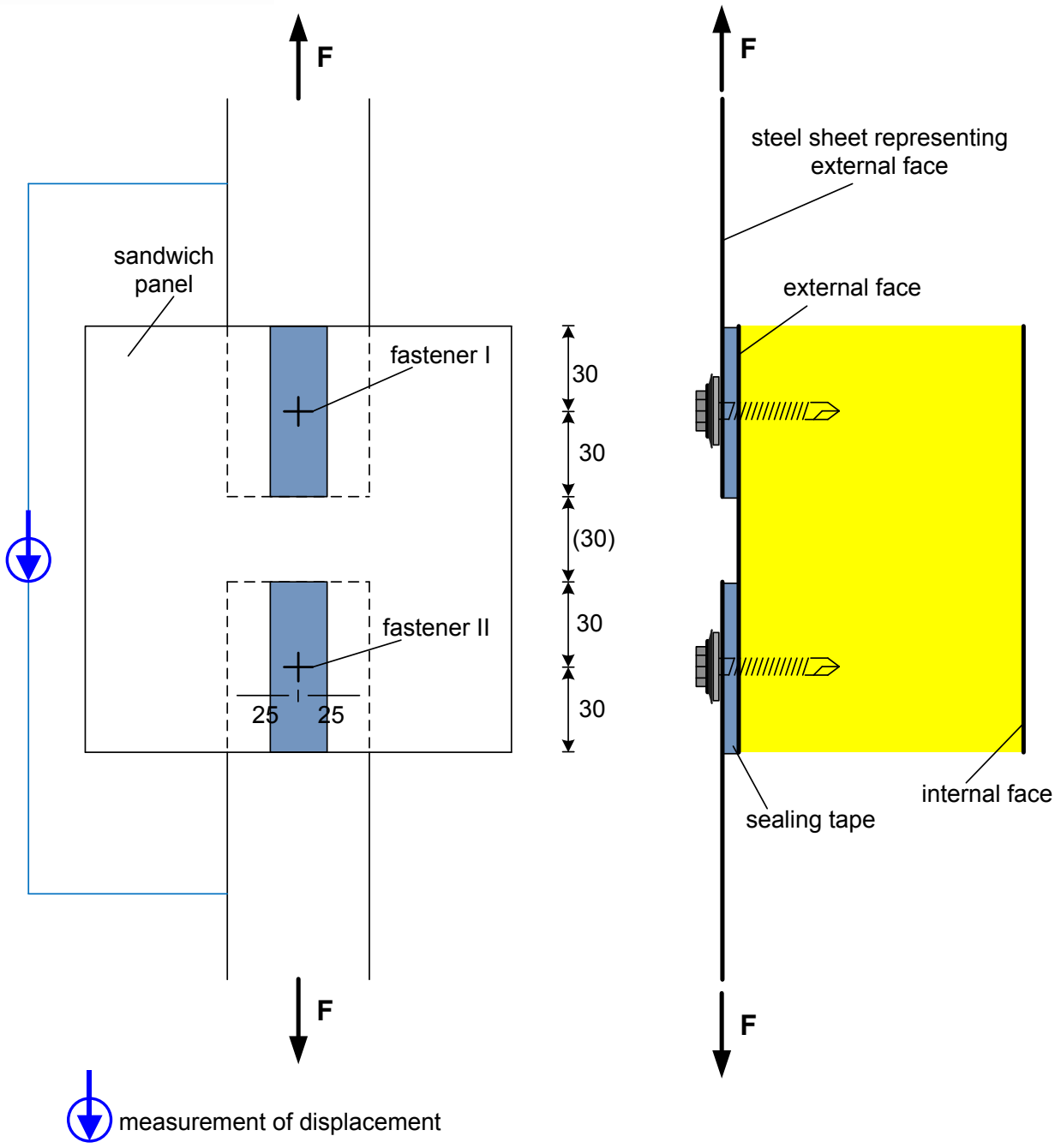


Fig. 13: Test set-up for tests on connection of longitudinal joints

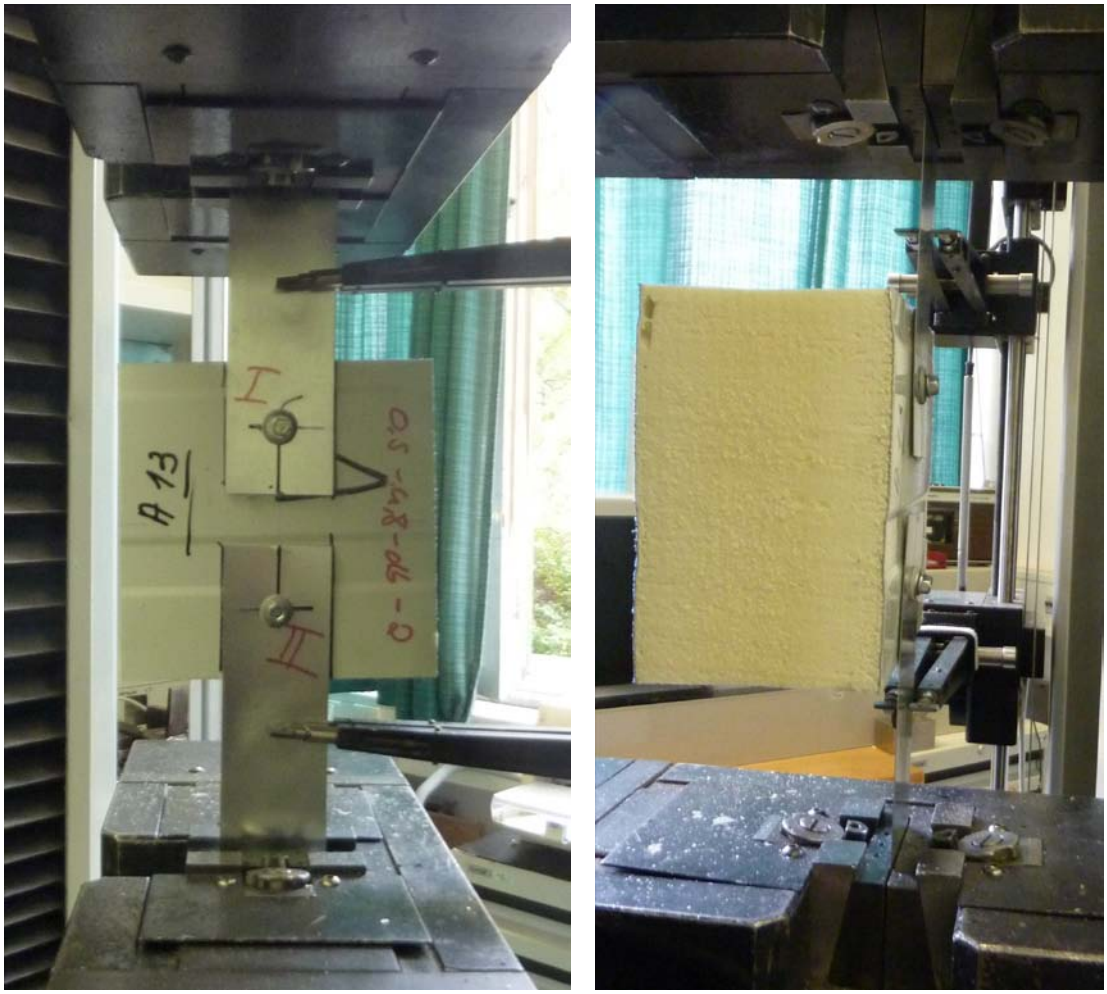


Fig. 14: Test set-up for tests on connection of longitudinal joints

During the tests the thickness of the face sheets as well as the nominal diameter of the fasteners were varied. Tab. 15 shows a compilation of the tests on longitudinal joints. For the specimens with sealing tape before testing the thickness of the sealing tape was measured at the mounted specimen (Tab. 16).

The specimens were loaded with a displacement-rate of 2 mm/min until a displacement of approximately 6.0 mm was reached. After the test the specimen was unloaded to zero. The load-displacement-diagrams of the tests are shown in annex 6. Because fasteners with undercut were used for the test, demounting of the specimens and measurement of the elongated holes was not possible.

No.	fastener	pre-drilling diame-ter [mm]	type of panel / thickness of sheets [mm]	sealing tape
0,50-4,8	SL2-S-4,8x22	-	A / 0,50	no
0,50-5,5	SL2-S-5,5x27	-	A / 0,50	no
0,50-6,3	SL2-S-L12-6,3x28	-	A / 0,50	no
0,75-4,8	SL2-S-4,8x22	-	B / 0,75	no
0,75-5,5	SL2-S-5,5x27	-	B / 0,75	no
0,75-6,3	SL2-S-L12-6,3x28	-	B / 0,75	no
0,50-4,8-st	SL2-S-4,8x22	-	A / 0,50	yes
0,50-5,5-st	SL2-S-5,5x27	-	A / 0,50	yes
0,50-6,3-st	SL2-S-L12-6,3x28	-	A / 0,50	yes
0,75-4,8-st	SL2-S-4,8x22	-	B / 0,75	yes
0,75-5,5-st	SL2-S-5,5x27	-	B / 0,75	yes
0,75-6,3-st	SL2-S-L12-6,3x28	-	B / 0,75	yes

Tab. 15: Compilation of full-scale tests on longitudinal joints

No.	thickness of sealing tape [mm]	No.	thickness of sealing tape [mm]
0,50-4,8-st-1-I	1,75	0,75-4,8-st-1-I	1,75
0,50-4,8-st-1-II	1,75	0,75-4,8-st-1-II	2,00
0,50-4,8-st-2-I	1,50	0,75-4,8-st-2-I	2,00
0,50-4,8-st-2-II	1,75	0,75-4,8-st-2-II	2,00
0,50-4,8-st-3-I	1,75	0,75-4,8-st-3-I	1,75
0,50-4,8-st-3-II	1,75	0,75-4,8-st-3-II	1,75
0,50-5,5-st-1-I	1,50	0,75-5,5-st-1-I	1,75
0,50-5,5-st-1-II	2,00	0,75-5,5-st-1-II	1,50
0,50-5,5-st-2-I	2,00	0,75-5,5-st-2-I	1,75
0,50-5,5-st-2-II	1,75	0,75-5,5-st-2-II	1,75
0,50-5,5-st-3-I	2,00	0,75-5,5-st-3-I	1,50
0,50-5,5-st-3-II	1,75	0,75-5,5-st-3-II	1,75
0,50-6,3-st-1-I	1,75	0,75-6,3-st-1-I	2,00
0,50-6,3-st-1-II	1,50	0,75-6,3-st-1-II	1,50
0,50-6,3-st-2-I	1,50	0,75-6,3-st-2-I	2,00
0,50-6,3-st-2-II	1,50	0,75-6,3-st-2-II	1,50
0,50-6,3-st-3-I	1,75	0,75-6,3-st-3-I	1,75
0,50-6,3-st-3-II	1,75	0,75-6,3-st-3-II	1,75

Tab. 16: Thickness of sealing tapes

5 Tests on “thick to thin” connections

In frameless buildings often connections of comparatively thick steel sheets to only one face sheet of a sandwich panel are used. Because the EASIE project deals also with frameless buildings tests on this kind of connection were performed. In the tests the steel section was represented by a steel angle with a thickness of 2,0 mm. The specimen used for the tests is given in Fig. 15 and Fig. 16.

The same test set up and test procedure was used as per the tests on connections of longitudinal joints (Fig. 13 and Fig. 14).

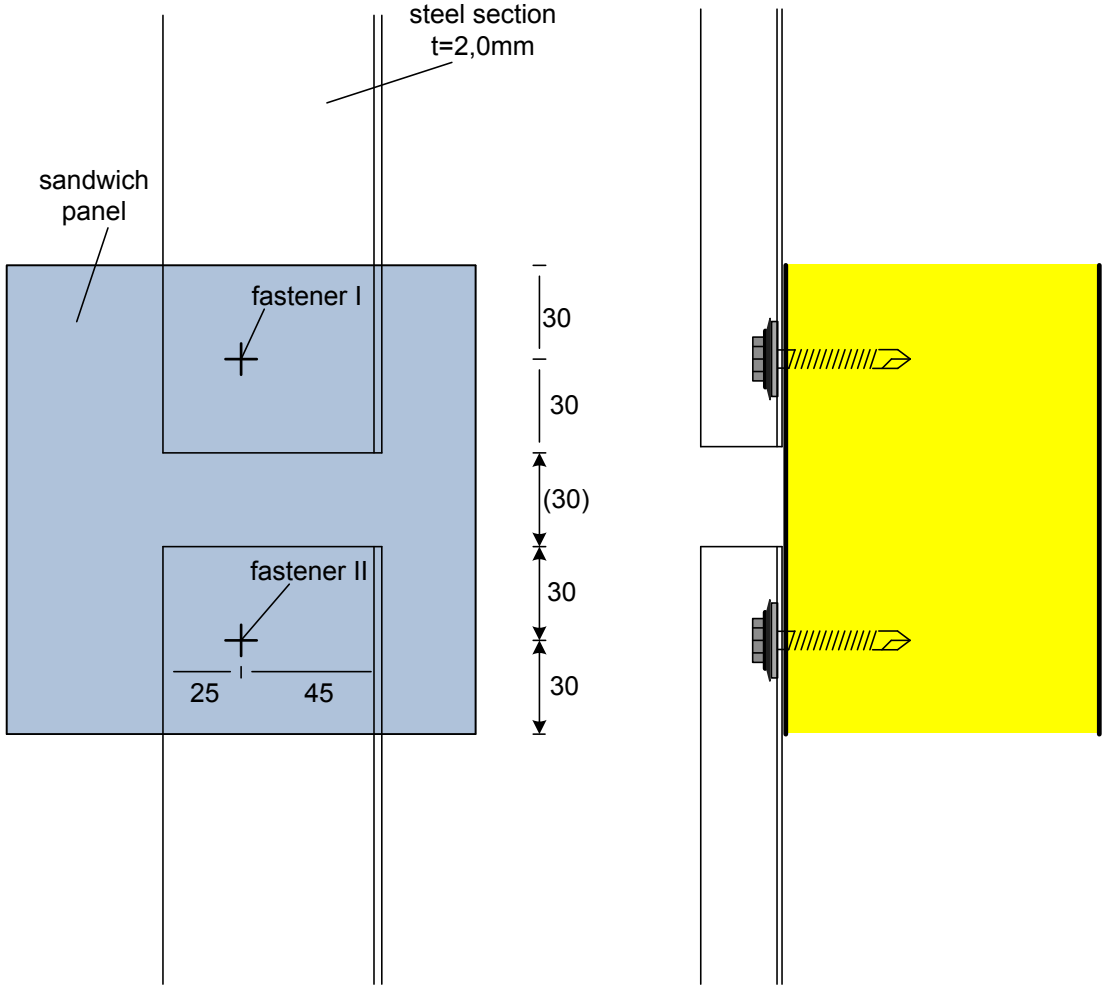


Fig. 15: Specimen for tests on “thick to thin” connections

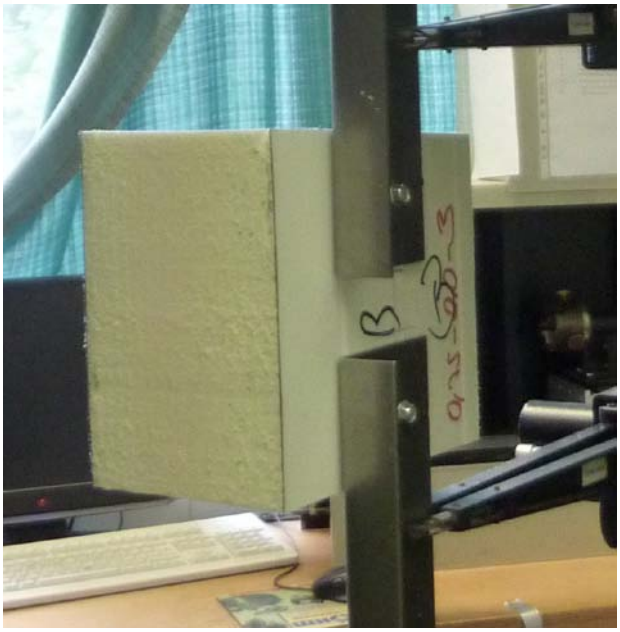


Fig. 16: Specimen for tests on "thick to thin" connections

Tab. 17 shows a compilation of the performed tests. The load-displacement-diagrams of the tests are shown in annex 7.

No.	fastener	pre-drilling diameter [mm]	thickness of steel sheet [mm]	type of panel / thickness of face sheet [mm]
2,00-0,50-JT3/2	JT3-2-6,0x25	-	2,0	A / 0,50
2,00-0,50-SL3/2	SL3/2-5-S-SV16-6,0xL	-	2,0	A / 0,50
2,00-0,75-JT3/2	JT3-2-6,0x25	-	2,0	B / 0,75
2,00-0,75-SL3/2	SL3/2-5-S-SV16-6,0xL	-	2,0	B / 0,75

Tab. 17: Compilation of tests

Demounting of the connections and measurement of the elongated holes was not possible for all specimens. If possible the specimens were demounted and the dimensions of the elongated holes were measured. The measured dimensions are given in Tab. 18.

No.	dimensions of elongated hole in the face sheet [mm]			
	fastener I		fastener II	
	lengthwise	crosswise	lengthwise	crosswise
2,00-0,50-SL3/2-1	5,43	3,75	6,91	3,66
2,00-0,50-SL3/2-2	4,83	4,00	7,80	3,94
2,00-0,50-SL3/2-3	5,80	4,17	6,99	3,66
2,00-0,75-SL3/2-1	5,78	3,89	5,30	3,71
2,00-0,75-SL3/2-2	6,60	3,91	5,75	3,62
2,00-0,75-SL3/2-3	5,21	3,70	6,28	3,80

Tab. 18: Measured dimensions of elongated holes

6 Mechanical properties of steel sheets and metallic surface layers

For each tested type of steel sheet and hollow section and for the face sheets of each tested type of sandwich panel, specimens for tensile tests according to EN 10002-1 were worked out and tensile tests for determining the mechanical properties were done. For determination of the yield strength $R_{eH}/R_{p0,2}$ and the tensile strength R_m, the core thicknesses t_k determined on the specimens were used. The mean values of the results are listed in the following tables.

t	t_K	$R_{eH}/R_{p0,2}$	R_m
[mm]	[mm]	[N/mm²]	[N/mm²]
0,40	0,38	329	390
0,50	0,49	341	405
0,75	0,69	266	387
1,00	0,97	322	394

Tab. 19: Mechanical properties of steel sheets for hole elongation tests and tests on longitudinal joints

t	t_K	$R_{eH}/R_{p0,2}$	R_m
[mm]	[mm]	[N/mm²]	[N/mm²]
2,00	1,81	332	398
3,00	2,75	380	446
4,00	4,12	467	523
5,00	4,88	469	497
6,00	5,70	401	457
8,00	7,80	392	539

Tab. 20: Mechanical properties of hollow sections for bending tests

t	t_K	$R_{eH}/R_{p0,2}$	R_m
[mm]	[mm]	[N/mm²]	[N/mm²]
2,00	2,01	163	308
3,00	3,07	398	492
4,00	3,87	343	460
5,00	5,39	326	499
6,00	6,16	352	455
8,00	7,92	341	446

Tab. 21: Mechanical properties of steel sheets used as substructure in full-scale tests

type of panel		t_K	$R_{eH}/R_{p0,2}$	R_m
		[mm]	[N/mm²]	[N/mm²]
A	top side of production	0,474	358	405
	bottom side of production	0,472	358	403
B	top side of production	0,765	399	403
	bottom side of production	0,759	406	402
C	face 1	0,538	412	456
	face 2	0,541	406	453

Tab. 22: Mechanical properties of face sheets of sandwich panels

7 Summary

WP 3, task 3.3 of the EASIE project deals with shear diaphragms made of sandwich panels. Because the in-plane shear stiffness of sandwich panels is significantly higher than the stiffness of the connections, the connections are decisive for the stiffness and load-bearing capacity of shear diaphragms. Therefore tests on connections of sandwich panels have been performed. In deliverable D3.2 – part 2 the results of the tests are presented. The evaluation of the test results can be found in deliverable D3.3. Deliverable D3.3 is also dealing with the design of diaphragms made of sandwich panels.

8 References

[1] The testing of Connections with Mechanical Fasteners in Steel Sheeting and Sections, ECCS-recommendation No. 124, 2009

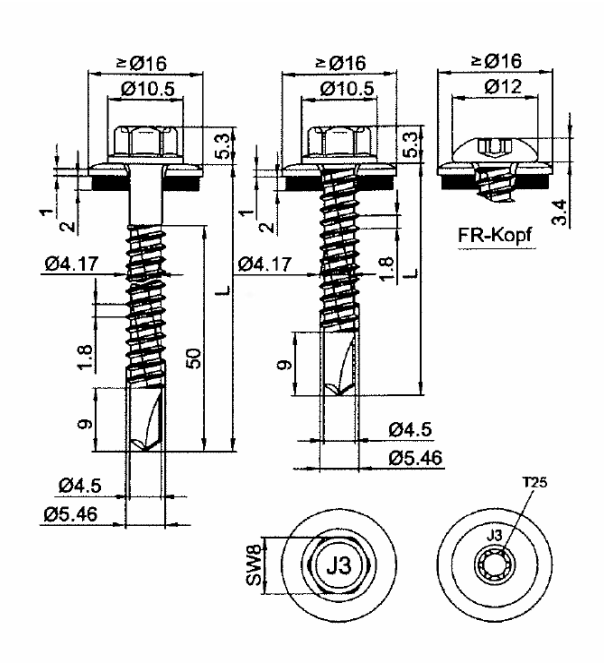
[2] Preliminary European Recommendations for the Testing and Design of Fastenings for Sandwich Panels, ECCS-recommendation No.127, 2009

[3] Allgemeine bauaufsichtliche Zulassung Z-14.1-4: Verbindungselemente zur Verbindung von Bauteilen im Metallleichtbau, Deutsches Institut für Bautechnik, 2005

[4] Allgemeine bauaufsichtliche Zulassung Z-14.4-407: Gewindeformende Schrauben zur Verbindung von Sandwichelementen mit Unterkonstruktionen aus Stahl oder Holz, Deutsches Institut für Bautechnik, 2006

[5] Allgemeine bauaufsichtliche Zulassung Z-14.1-537: Mechanische Verbindungselemente zur Verbindung von Bauteilen aus Aluminium miteinander oder mit Unterkonstruktionen aus Aluminium, Stahl oder Holz, Deutsches Institut für Bautechnik, 2008

JT3-6-5,5xL



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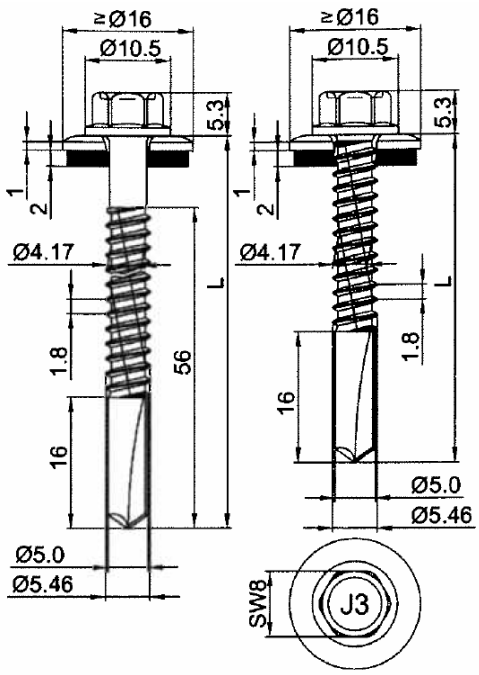

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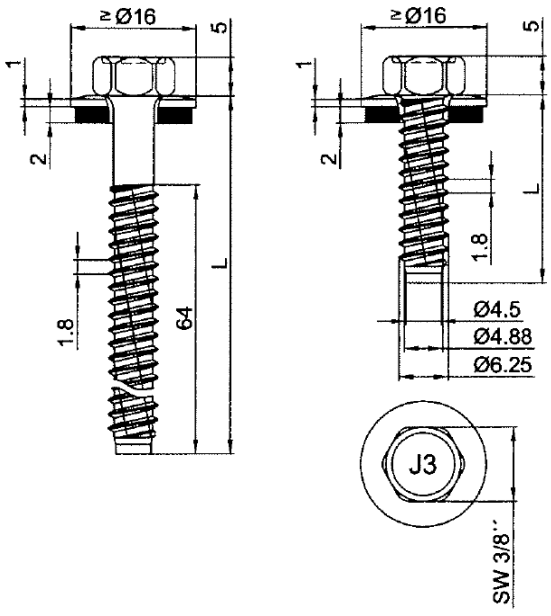

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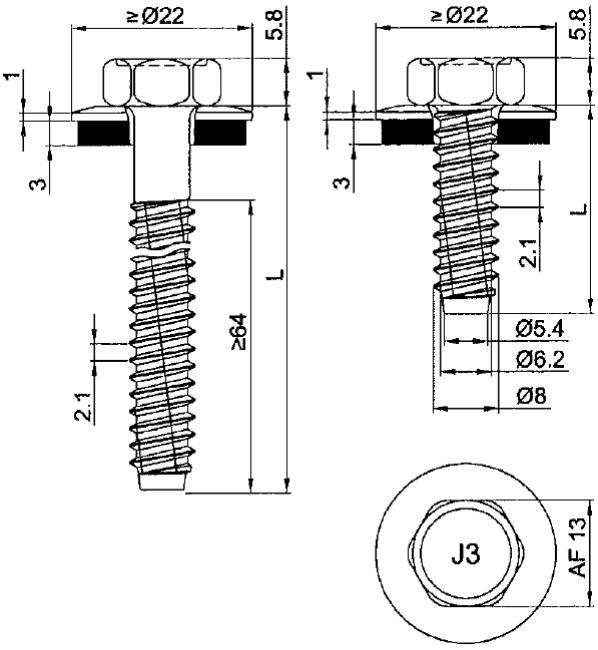

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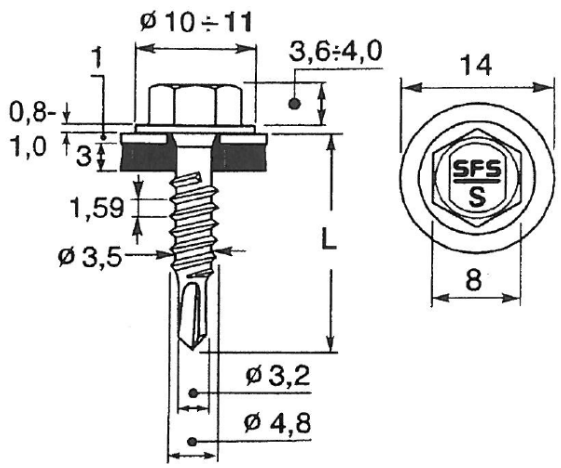

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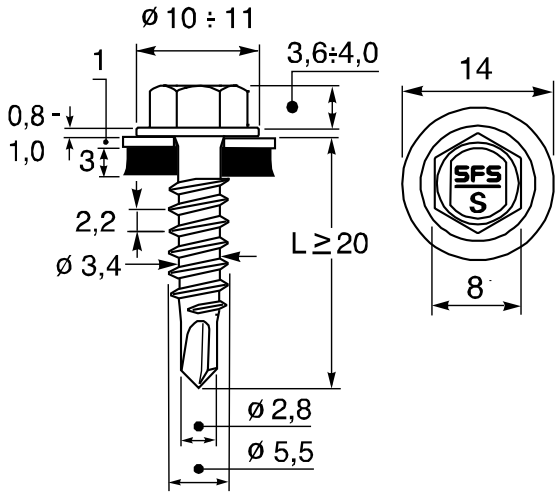

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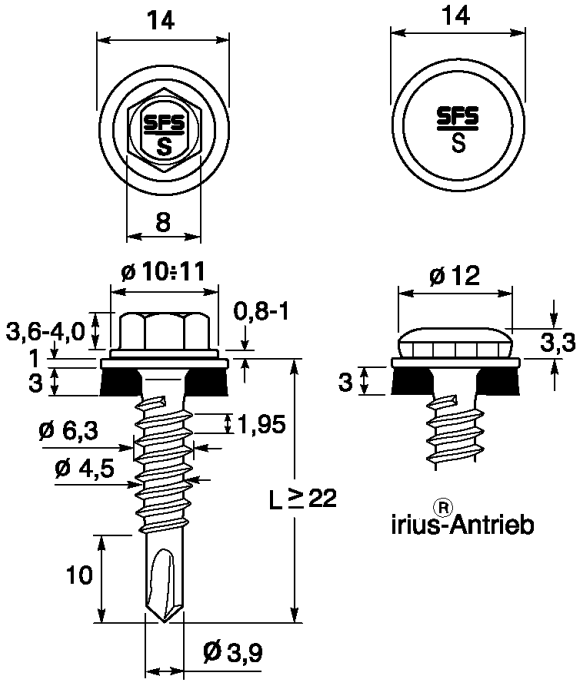

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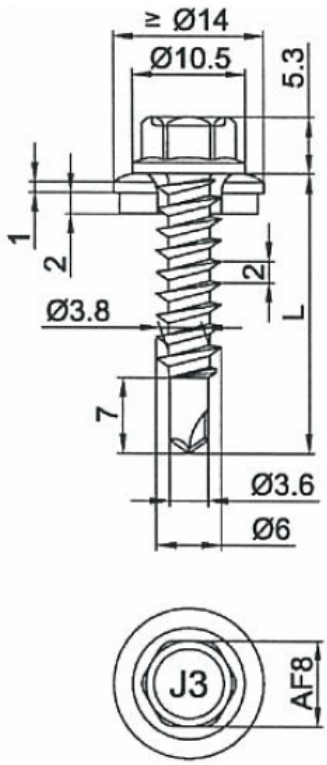

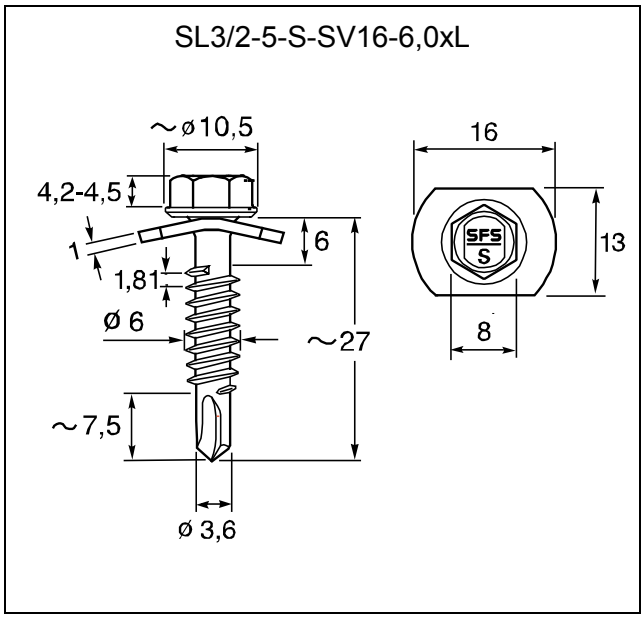
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1,81
6
ø 6
~27
~7,5
ø 3,6
16
13
8
SFS
S

Measured dimensions of fastener **JT3-6-5,5x130**

No.	external diameter	core diameter	thread pitch	length of thread	diameter of shaft	pin diameter	length of pin
1	5,58	3,97	1,93	40,17	4,53	4,64	9,12
2	5,51	3,96	1,93	41,03	4,53	4,57	8,46
3	5,55	3,96	1,93	40,17	4,52	4,77	9,08
4	5,53	3,96	1,91	40,74	4,52	4,59	8,50
5	5,53	3,97	1,93	40,88	4,52	4,65	8,45
6	5,52	3,98	1,94	41,03	4,52	4,70	8,03
7	5,56	3,96	1,84	40,79	4,54	4,69	8,51
8	5,51	3,96	1,83	41,41	4,53	4,73	8,08
9	5,49	3,97	1,83	40,88	4,51	4,63	8,46
10	5,49	3,97	1,83	40,41	4,53	4,60	8,93
mean values	5,53	3,96	1,89	40,75	4,53	4,66	8,56

Measured dimensions of fastener **JT3-6-5,5x170**

No.	external diameter	core diameter	thread pitch	length of thread	diameter of shaft	pin diameter	length of pin
1	5,47	4,02	1,82	40,27	4,52	4,70	9,50
2	5,50	4,06	1,83	40,32	4,52	4,71	9,64
3	5,49	4,01	1,83	40,94	4,52	4,80	8,78
4	5,49	4,02	1,83	41,80	4,53	4,71	8,36
5	5,48	4,01	1,82	41,52	4,52	4,64	8,69
6	5,48	4,02	1,83	41,37	4,53	4,76	8,98
7	5,48	4,01	1,82	40,89	4,53	4,70	8,88
8	5,50	4,02	1,83	41,18	4,53	4,76	8,64
9	5,48	4,03	1,82	40,18	4,55	4,71	9,55
10	5,48	4,02	1,82	40,94	4,52	4,76	9,02
mean values	5,48	4,02	1,83	40,94	4,53	4,72	9,00

Measured dimensions of fastener **JT3-12-5,5x138**

No.	external diameter	core diameter	thread pitch	length of thread	diameter of shaft	pin diameter	length of pin
1	5,46	4,01	1,83	41,63	4,53	4,05	16,16
2	5,38	4,03	1,83	41,96	4,53	4,04	16,12
3	5,48	4,02	1,83	41,58	4,58	4,06	16,31
4	5,53	4,02	1,83	41,73	4,57	4,07	16,30
5	5,48	4,00	1,82	41,73	4,53	4,05	16,06
6	5,40	4,05	1,83	41,73	4,55	4,07	16,21
7	5,45	4,01	1,83	42,01	4,53	4,05	15,78
8	5,44	4,00	1,82	41,34	4,53	4,10	16,36
9	5,50	4,02	1,83	41,58	4,52	4,07	16,16
10	5,62	4,00	1,82	42,53	4,54	4,06	15,31
mean values	5,47	4,01	1,83	41,78	4,54	4,06	16,08

Measured dimensions of fastener **JT3-12-5,5x178**

No.	external diameter	core diameter	thread pitch	length of thread	diameter of shaft	pin diameter	length of pin
1	5,45	4,05	1,83	45,33	4,51	4,98	11,84
2	5,41	4,05	1,84	45,71	4,52	4,90	11,27
3	5,42	4,02	1,82	42,08	4,50	4,90	14,66
4	5,39	4,05	1,83	44,95	4,52	4,87	12,08
5	5,37	4,05	1,83	41,84	4,51	4,93	15,18
6	5,43	4,04	1,83	44,28	4,52	4,93	12,89
7	5,35	4,06	1,83	45,09	4,52	4,92	11,70
8	5,38	4,06	1,83	43,80	4,52	4,91	13,46
9	5,38	4,03	1,82	42,66	4,50	4,92	14,33
10	5,41	4,04	1,83	41,99	4,54	4,94	15,14
mean values	5,40	4,04	1,83	43,77	4,52	4,92	13,26

Measured dimensions of fastener **JZ3-6,3x150**

No.	external diameter	core diameter	thread pitch	length of thread	diameter of shaft	pin diameter	length of pin
1	6,23	4,76	1,83	64,16	5,26	4,51	-
2	6,31	4,78	1,82	64,44	5,26	4,47	-
3	6,22	4,78	1,82	65,04	5,27	4,47	-
4	6,22	4,78	1,82	64,75	5,24	4,51	-
5	6,28	4,72	1,82	64,52	5,25	4,51	-
6	6,23	4,75	1,82	65,67	5,24	4,42	-
7	6,24	4,73	1,82	64,37	5,25	4,51	-
8	6,30	4,73	1,82	64,90	5,23	4,47	-
9	6,25	4,79	1,82	65,18	5,26	4,47	-
10	6,25	4,76	1,82	65,37	5,24	4,47	-
mean values	6,25	4,76	1,82	64,84	5,25	4,48	-

Measured dimensions of fastener **JZ3-6,3x175**

No.	external diameter	core diameter	thread pitch	length of thread	diameter of shaft	pin diameter	length of pin
1	6,23	4,74	1,82	64,06	5,27	4,42	-
2	6,29	4,66	1,83	64,73	5,26	4,42	-
3	6,24	4,70	1,82	64,68	5,27	4,42	-
4	6,28	4,70	1,82	64,58	5,27	4,27	-
5	6,25	4,73	1,82	63,67	5,27	4,32	-
6	6,22	4,73	1,82	64,15	5,25	4,32	-
7	6,21	4,76	1,82	64,49	5,25	4,42	-
8	6,32	4,68	1,82	64,20	5,26	4,37	-
9	6,27	4,73	1,82	64,01	5,28	4,42	-
10	6,26	4,73	1,82	63,86	5,25	4,32	-
mean values	6,26	4,72	1,82	64,24	5,26	4,37	-

Measured dimensions of fastener **JZ3-8,0x150**

No.	external diameter	core diameter	thread pitch	length of thread	diameter of shaft	pin diameter	length of pin
1	7,95	6,14	2,14	64,36	6,79	5,43	-
2	7,93	6,12	2,13	64,31	6,80	5,48	-
3	7,96	6,13	2,14	64,16	6,81	5,29	-
4	7,97	6,12	2,13	63,59	6,79	5,43	-
5	7,95	6,13	2,14	64,16	6,81	5,48	-
6	7,99	6,13	2,14	64,21	6,82	5,48	-
7	7,95	6,13	2,13	64,26	6,82	5,48	-
8	7,93	6,11	2,13	64,31	6,82	5,38	-
9	8,02	6,12	2,13	65,17	6,80	5,48	-
10	7,95	6,12	2,13	64,31	6,82	5,43	-
mean values	7,96	6,12	2,13	64,28	6,81	5,44	-

Measured dimensions of fastener **SL2-S-4,8x22**

No.	external diameter	core diameter	thread pitch	length of thread	diameter of undercut	length of undercut	pin diameter	length of pin
1	4,70	3,27	1,59	10,74	3,60	5,06	2,63	7,53
2	4,66	3,25	1,58	11,93	3,58	5,00	2,68	6,39
3	4,63	3,23	1,59	11,02	3,55	5,08	2,65	7,01
4	4,68	3,27	1,59	11,93	3,60	5,06	2,64	6,34
5	4,68	3,28	1,59	11,93	3,66	4,93	2,65	6,29
6	4,72	3,29	1,59	11,79	3,58	5,11	2,64	6,39
7	4,65	3,26	1,58	11,12	3,61	5,02	2,64	7,22
8	4,73	3,27	1,59	11,74	3,59	5,08	2,63	6,44
9	4,72	3,30	1,60	11,93	3,58	4,70	2,64	6,53
10	4,71	3,28	1,59	11,93	3,58	5,00	2,63	6,25
mean values	4,69	3,27	1,59	11,60	3,59	5,00	2,64	6,64

Measured dimensions of fastener **SL2-S-5,5x27**

No.	external diameter	core diameter	thread pitch	length of thread	diameter of undercut	length of undercut	pin diameter	length of pin
1	5,40	3,12	2,22	13,62	3,29	5,22	2,31	8,06
2	5,44	3,09	2,21	14,29	3,32	5,24	2,32	7,49
3	5,47	3,10	2,22	14,05	3,36	4,99	2,30	7,96
4	5,35	3,10	2,22	13,76	3,29	5,26	2,33	7,73
5	5,33	3,10	2,22	13,57	3,30	5,07	2,35	8,25
6	5,41	3,10	2,22	13,71	3,31	5,18	2,33	7,96
7	5,43	3,07	2,20	13,71	3,27	5,36	2,25	7,82
8	5,36	3,13	2,16	14,05	3,28	5,22	2,32	7,82
9	5,38	3,10	2,21	14,62	3,31	5,19	2,32	7,35
10	5,42	3,10	2,21	13,57	3,33	5,02	2,31	8,35
mean values	5,40	3,10	2,21	13,89	3,30	5,17	2,31	7,88

Measured dimensions of fastener **SL2-S-L12-6,3x28**

No.	external diameter	core diameter	thread pitch	length of thread	diameter of undercut	length of undercut	pin diameter	length of pin
1	6,30	4,33	1,96	12,66	4,72	4,83	3,94	10,65
2	6,31	4,31	1,95	12,51	4,72	5,14	3,92	10,26
3	6,36	4,34	1,97	13,66	4,72	4,21	3,92	10,17
4	6,32	4,28	1,94	12,70	4,70	4,94	3,96	10,22
5	6,28	4,31	1,96	13,04	4,73	4,22	3,89	10,60
6	6,30	4,34	1,96	11,00	4,75	3,70	3,89	10,17
7	6,28	4,33	1,96	13,32	4,71	4,90	3,90	9,88
8	6,32	4,30	1,95	12,66	4,73	5,01	3,90	10,24
9	6,28	4,31	1,94	12,28	4,73	5,27	3,93	10,52
10	6,30	4,29	1,96	12,61	4,78	5,03	3,94	10,44
mean values	6,30	4,31	1,96	12,64	4,73	4,73	3,92	10,31

Measured dimensions of fastener **JT3-2-6,0x25**

No.	external diameter	core diameter	thread pitch	length of thread	diameter of undercut	length of undercut	pin diameter	length of pin
1	5,88	3,64	2,00	17,17	4,56	1,93	3,73	6,94
2	5,88	3,64	2,00	16,07	4,58	2,57	3,74	7,47
3	5,86	3,63	2,00	16,07	4,52	2,08	3,76	7,89
4	5,88	3,64	1,99	16,31	4,56	2,39	3,74	7,42
5	5,88	3,65	2,00	17,02	4,58	1,95	3,73	7,08
6	5,87	3,64	2,00	16,07	4,55	1,94	3,74	8,23
7	5,89	3,63	2,00	16,93	4,56	1,88	3,71	7,13
8	5,87	3,64	2,00	16,83	4,56	2,01	3,74	7,18
9	5,88	3,64	1,99	16,59	4,55	2,32	3,75	6,89
10	5,89	3,64	2,00	16,59	4,55	1,86	3,78	7,18
mean values	5,88	3,64	2,00	16,56	4,56	2,09	3,74	7,34

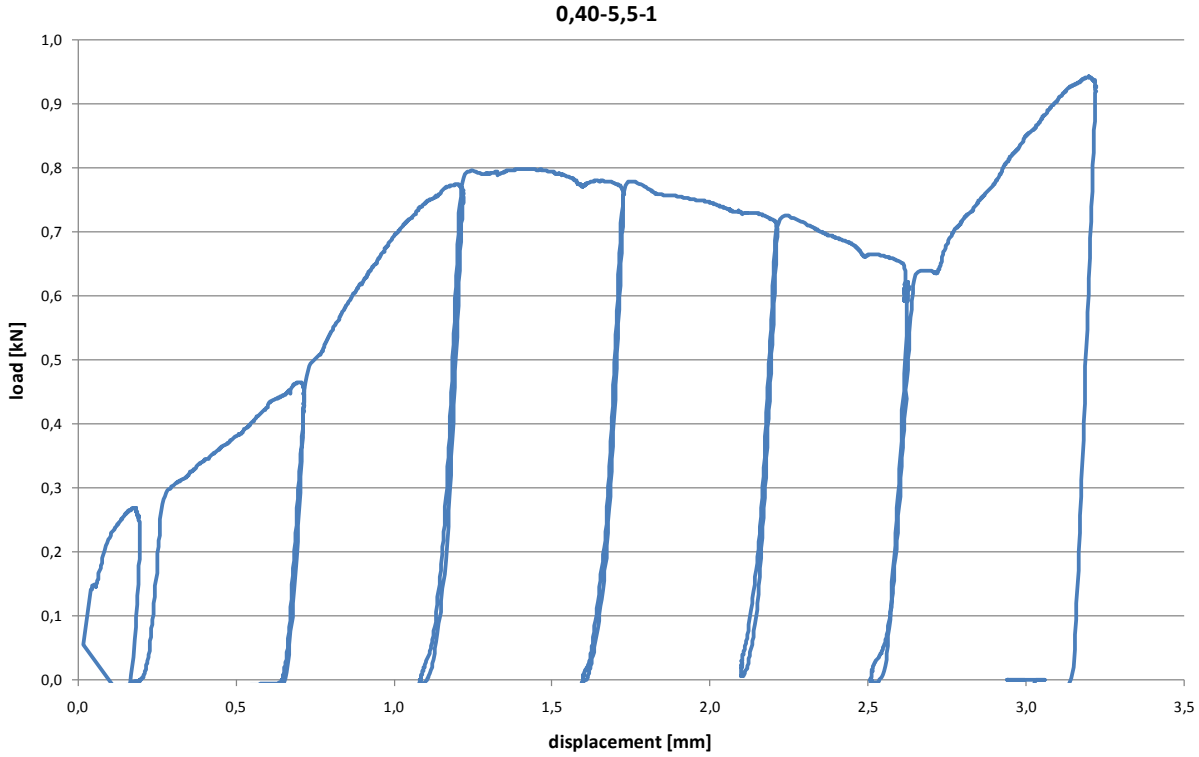
Measured dimensions of fastener **SL3/2-5-S-SV16-6,0x27**

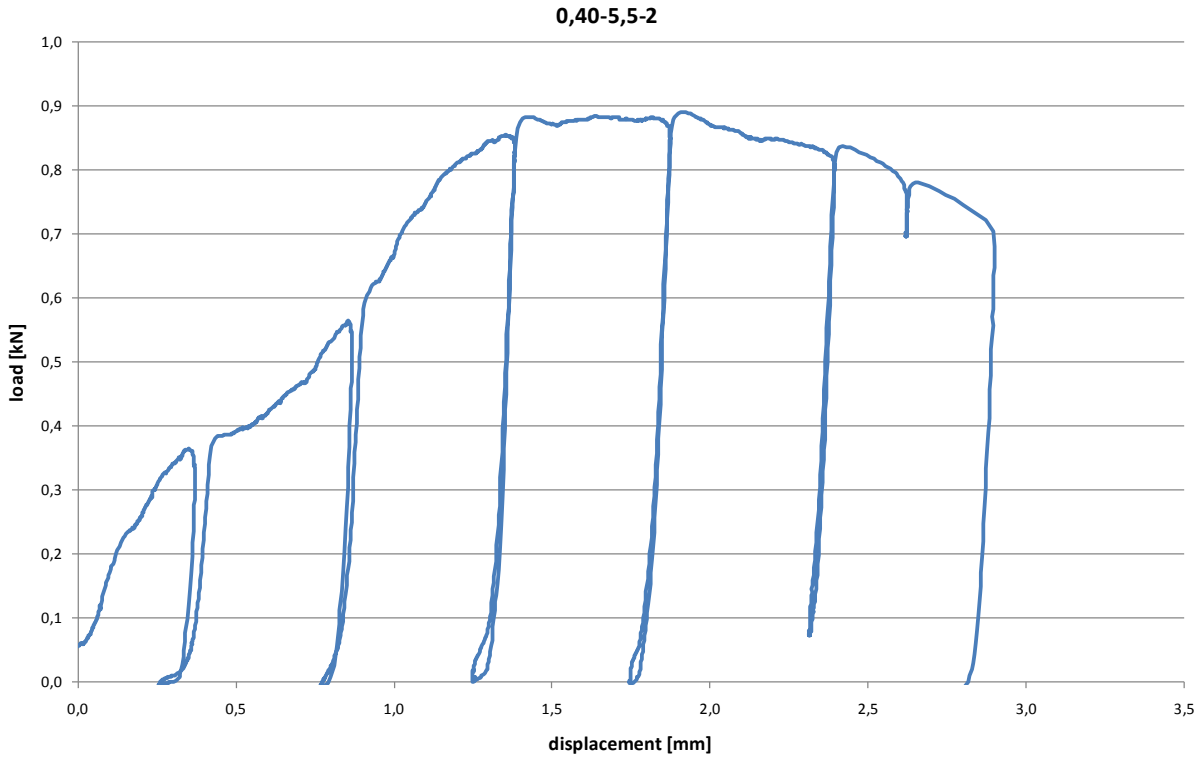
No.	external diameter	core diameter	thread pitch	length of thread	diameter of undercut	length of undercut	pin diameter	length of pin
1	5,97	3,55	1,82	13,54	3,57	6,80	3,64	7,13
2	6,00	3,56	1,83	14,14	3,56	6,56	3,53	6,74
3	5,98	3,56	1,82	14,05	3,58	6,72	3,69	6,79
4	6,00	3,56	1,82	13,77	3,59	6,77	3,64	6,98
5	5,99	3,55	1,82	13,41	3,59	6,81	3,54	7,31
6	5,99	3,55	1,82	13,90	3,58	6,95	3,54	6,55
7	5,97	3,55	1,82	15,22	3,56	6,74	3,59	5,45
8	5,99	3,56	1,82	13,85	3,57	6,86	3,61	6,94
9	5,98	3,56	1,81	16,15	3,57	6,66	3,61	4,59
10	6,00	3,55	1,81	14,91	3,63	6,65	3,67	5,88
mean values	5,99	3,55	1,82	14,29	3,58	6,75	3,61	6,44

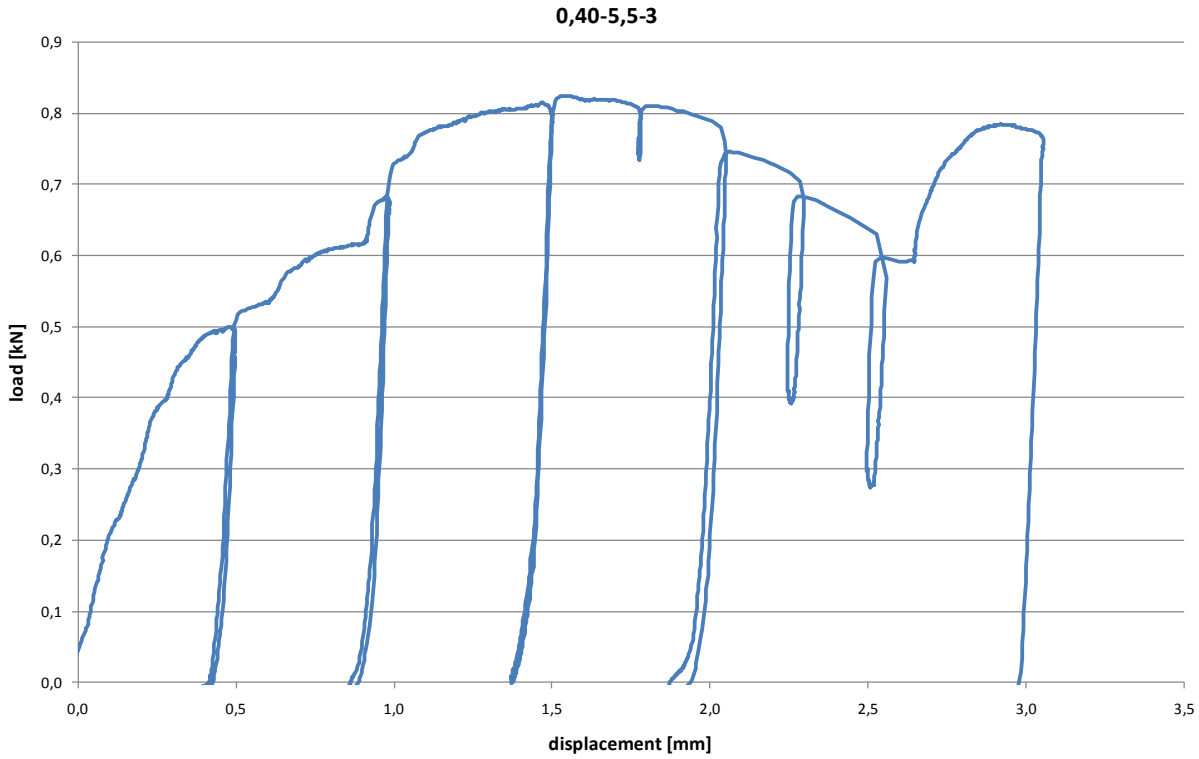
Hole elongation tests

thickness of steel sheet: 0,40 mm

nominal diameter of fastener: 5,5 mm



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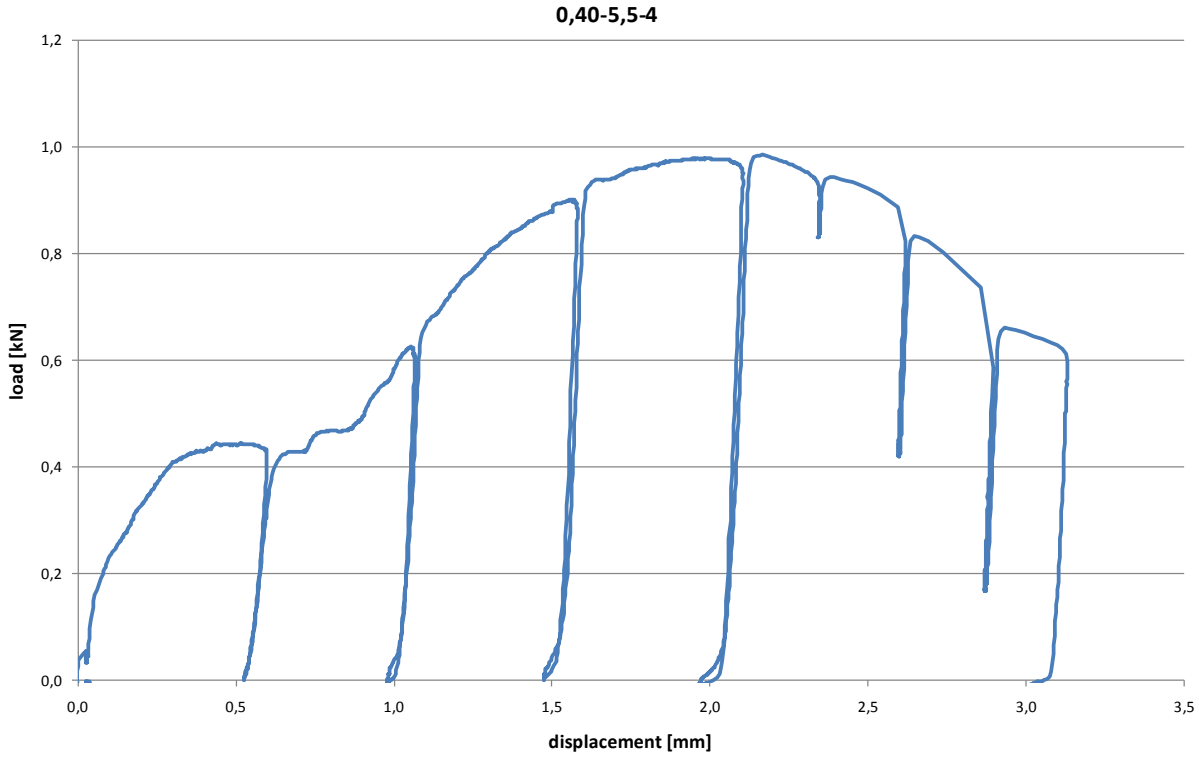
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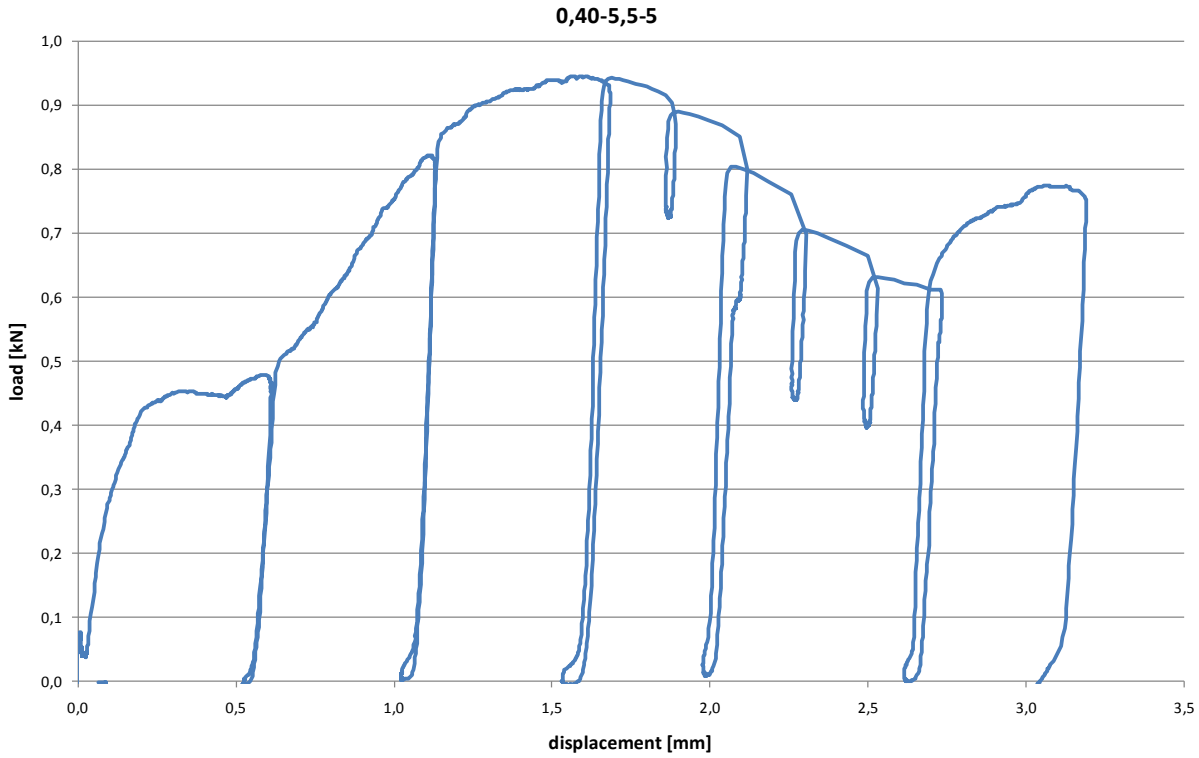
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0,5
1,0
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2,5
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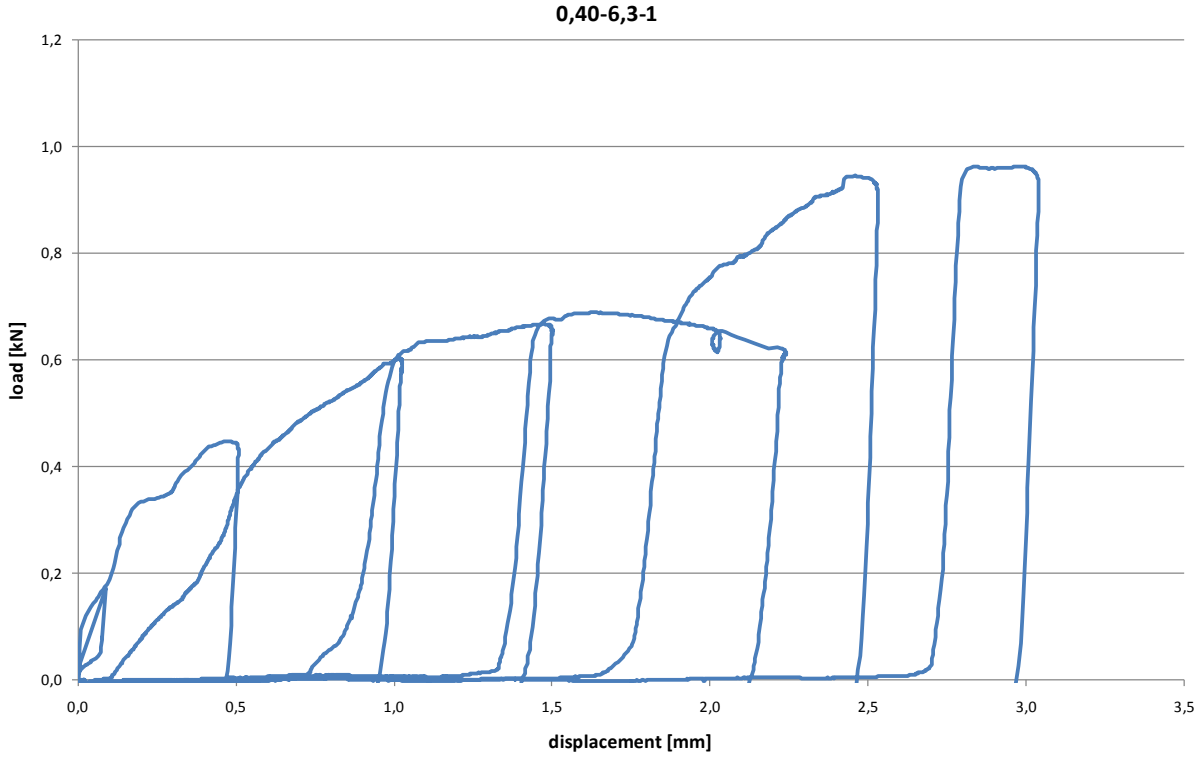
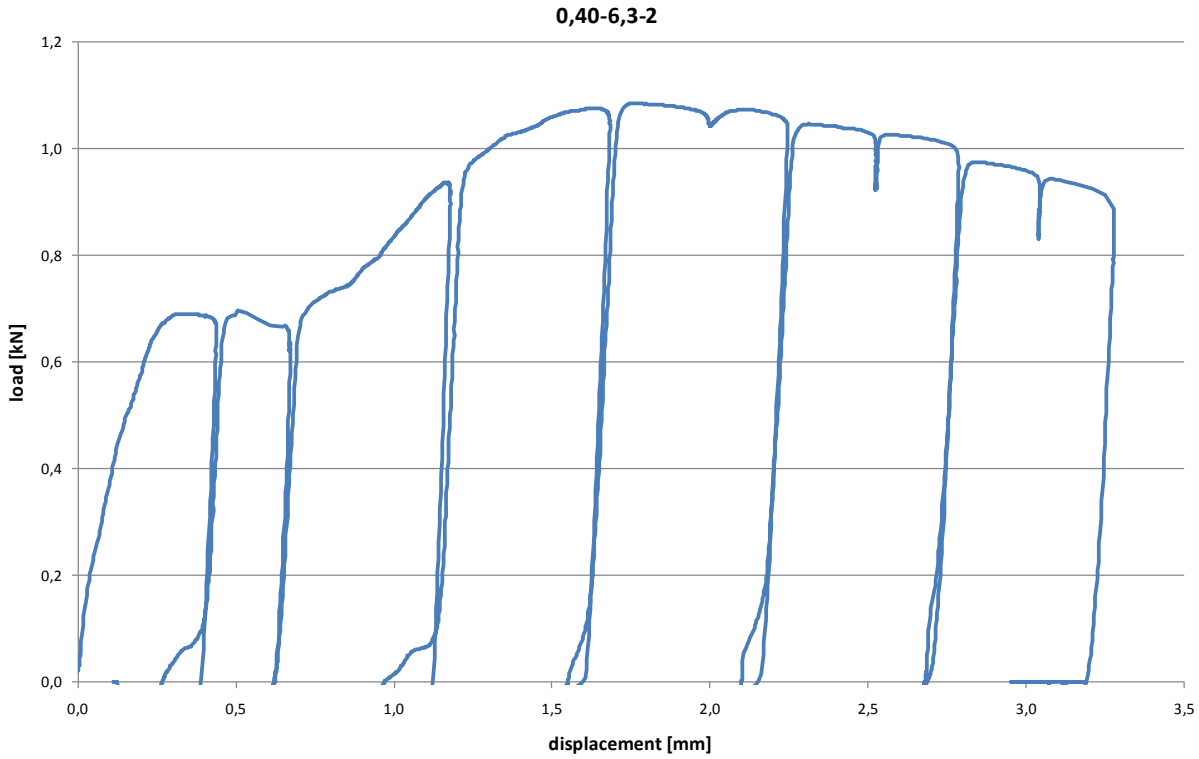
3,5

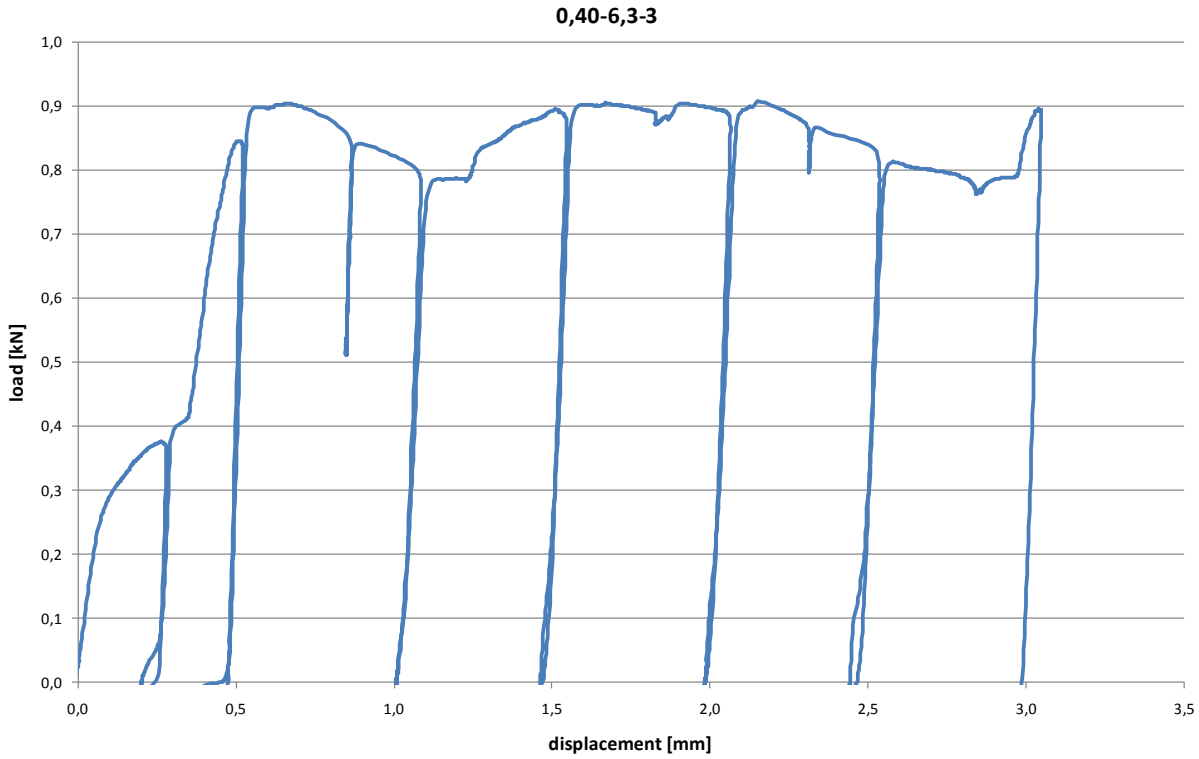
Hole elongation tests

thickness of steel sheet: 0,40 mm

nominal diameter of fastener: 6,3 mm



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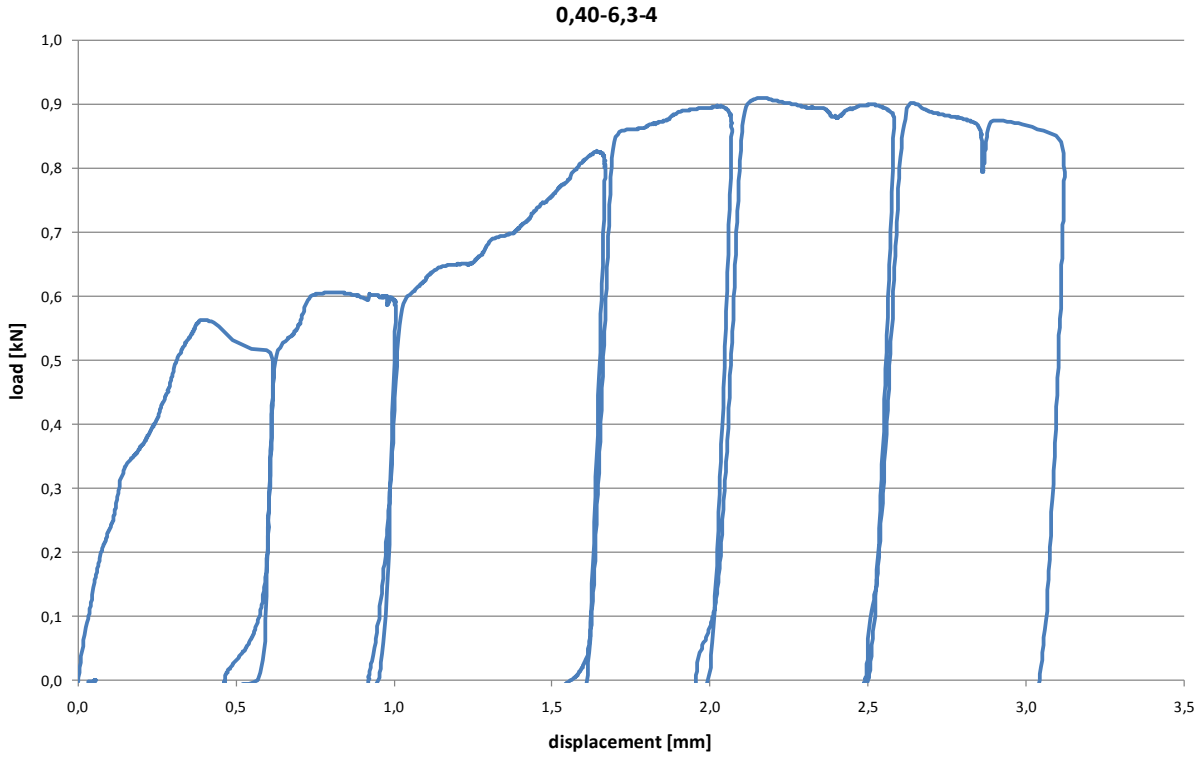
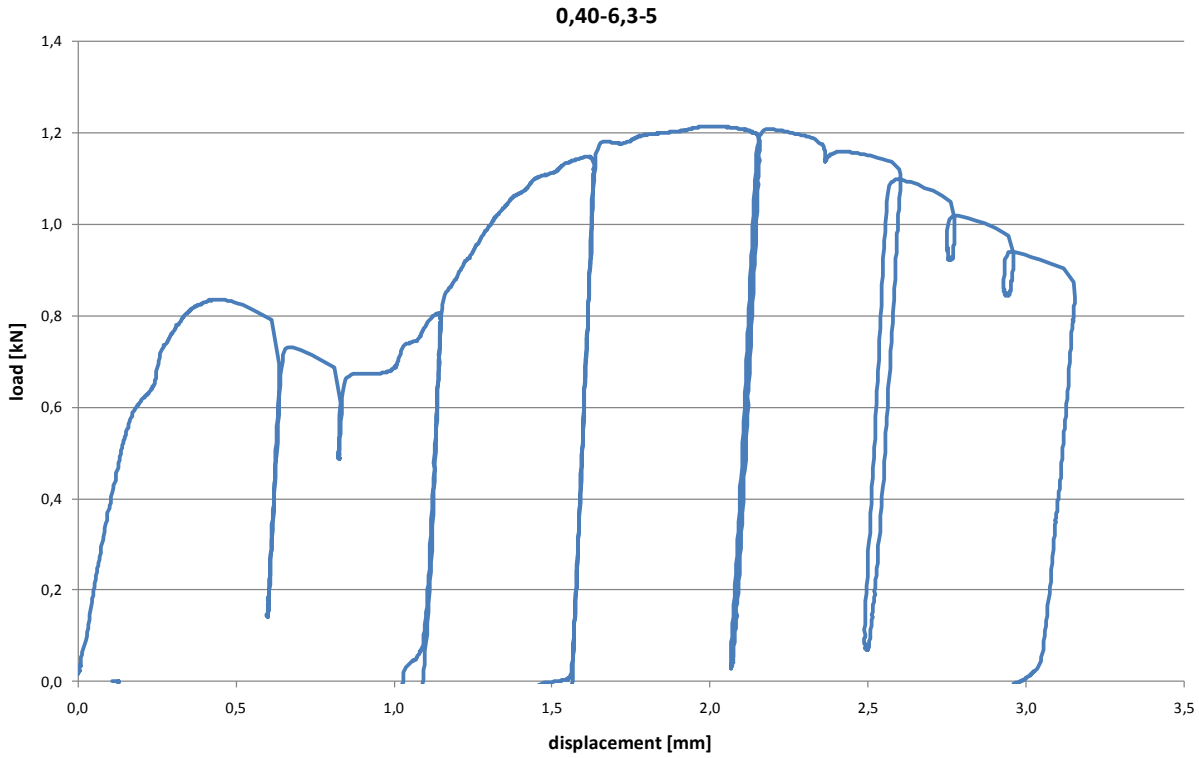
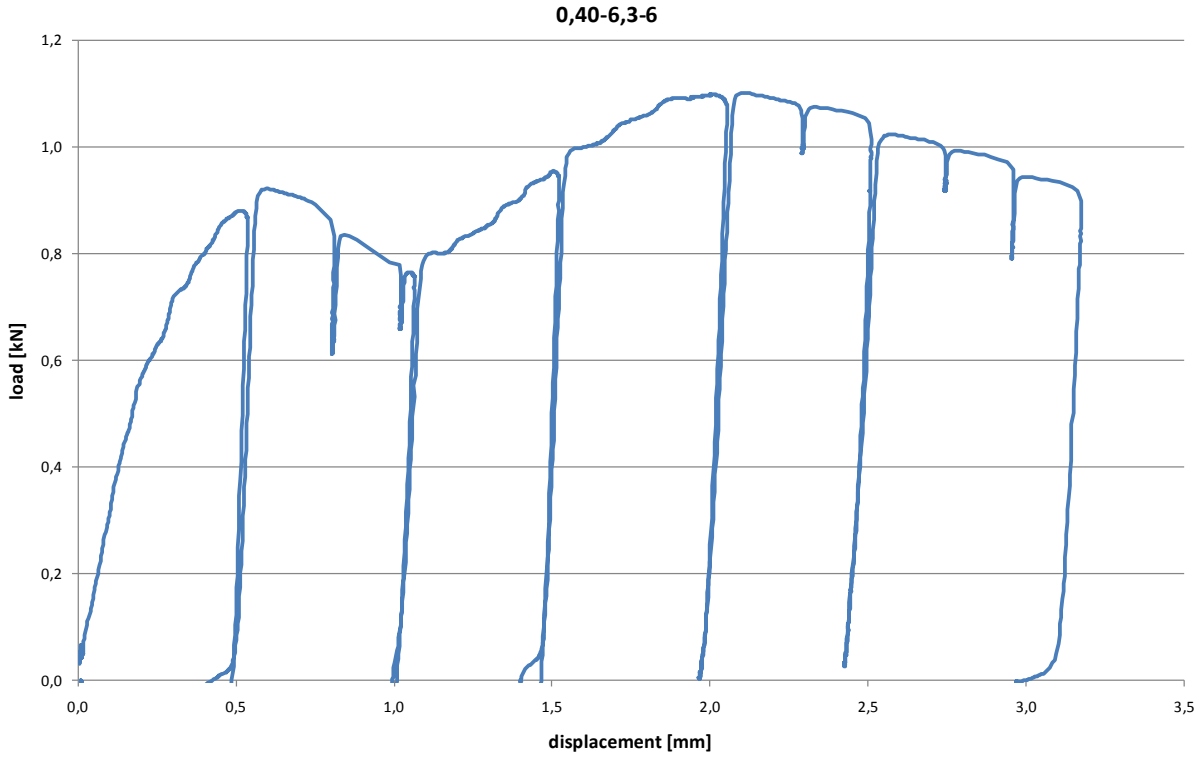
0,2
0,1
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5


0,40-6,3-4
load [kN]
displacement [mm]
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5

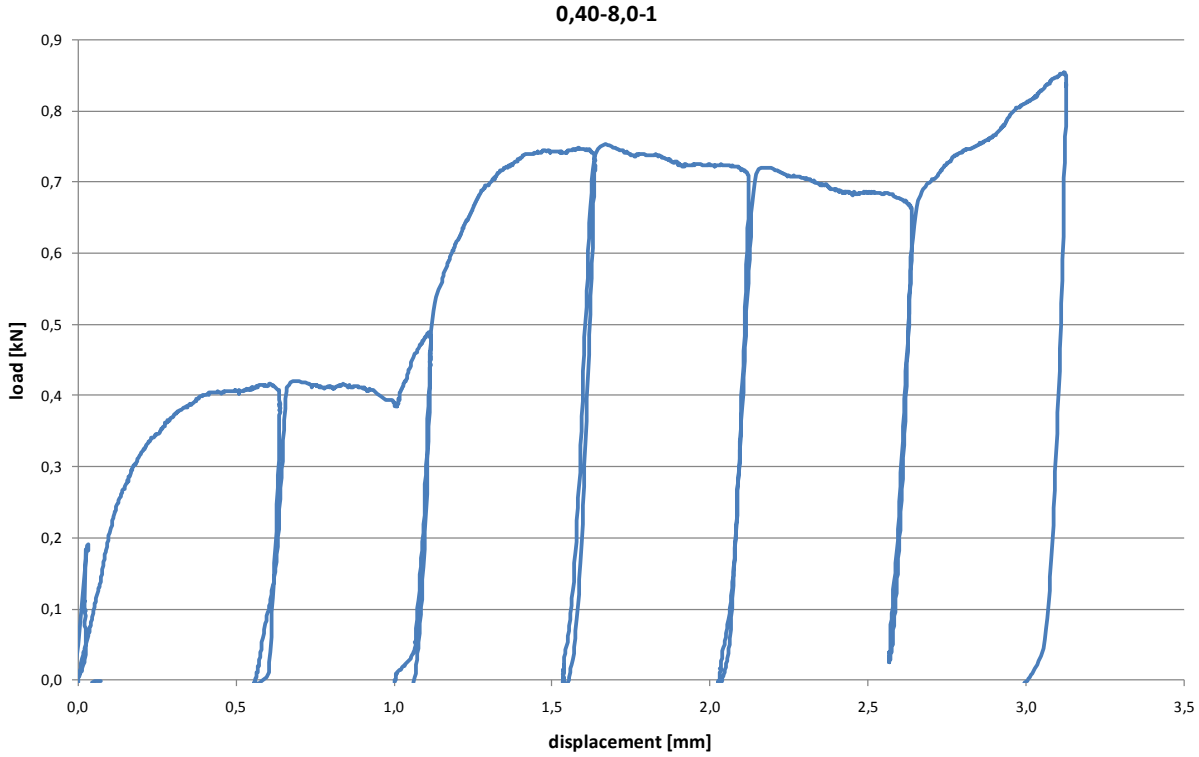

0,40-6,3-5
load [kN]
displacement [mm]
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5

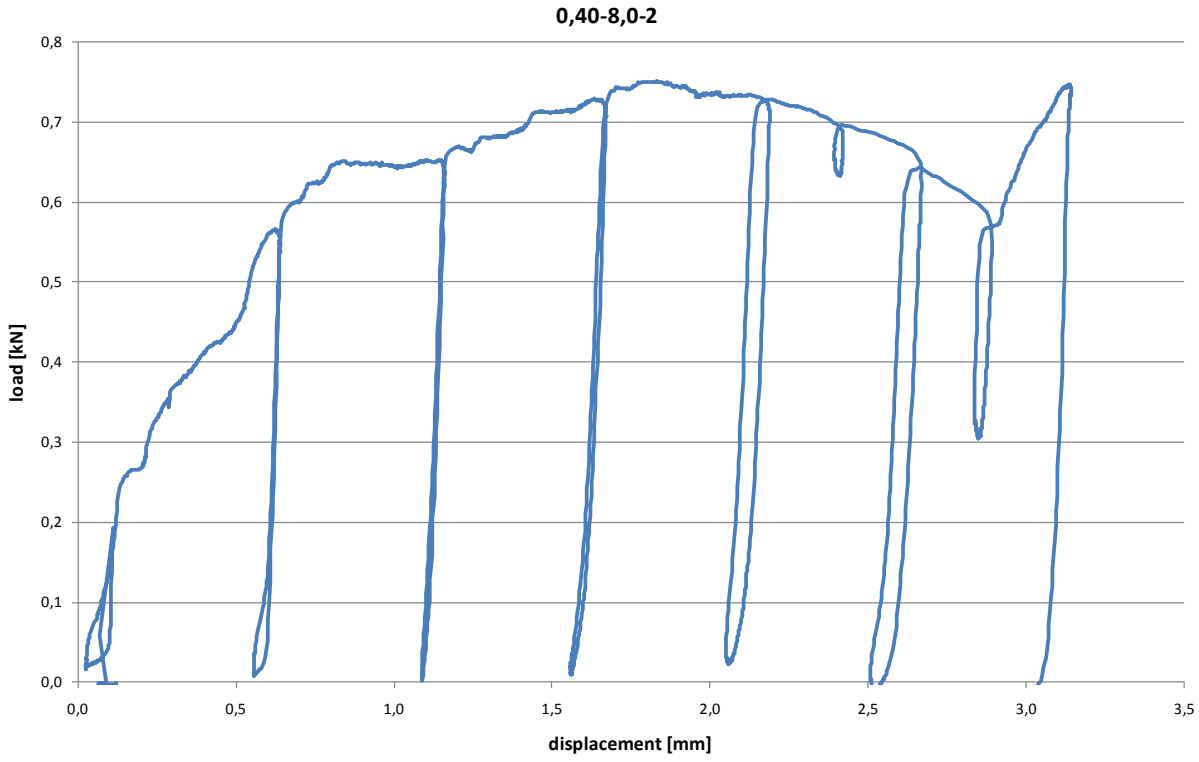

0,40-6,3-6
load [kN]
displacement [mm]
1,2
1,0
0,8
0,6
0,4
0,2
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5

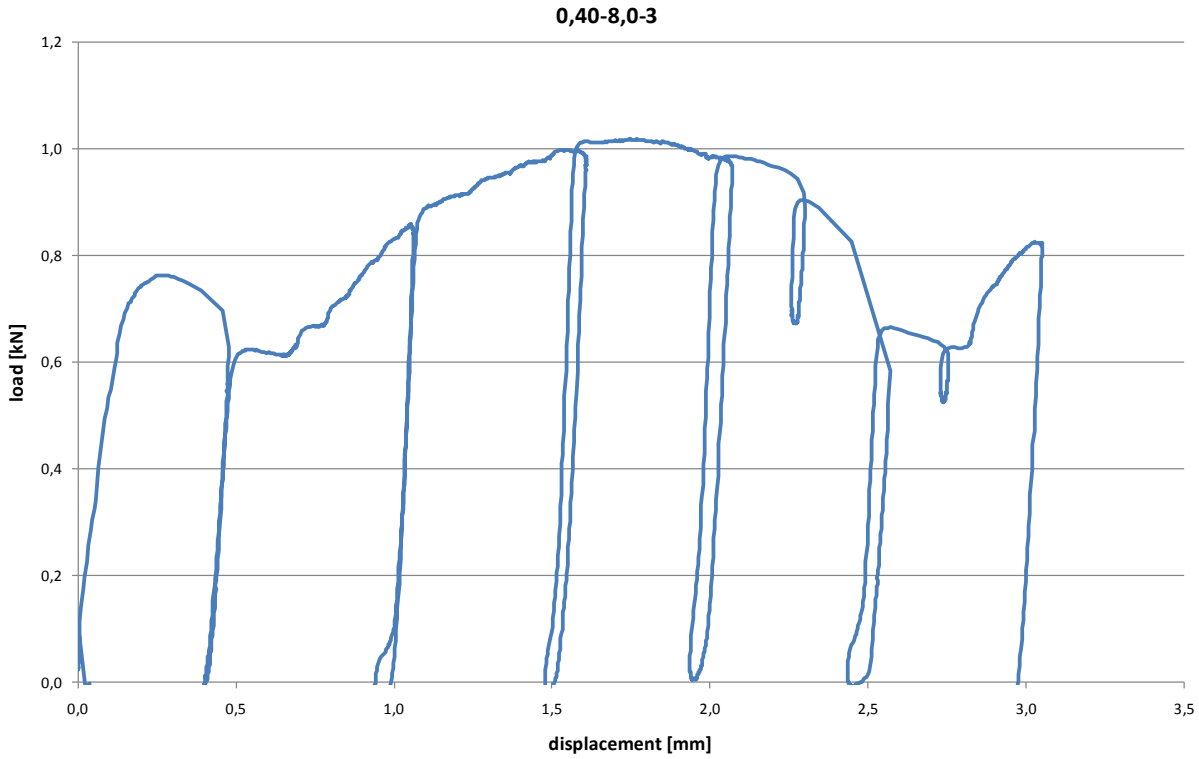
Hole elongation tests

thickness of steel sheet: 0,40 mm

nominal diameter of fastener: 8,0 mm



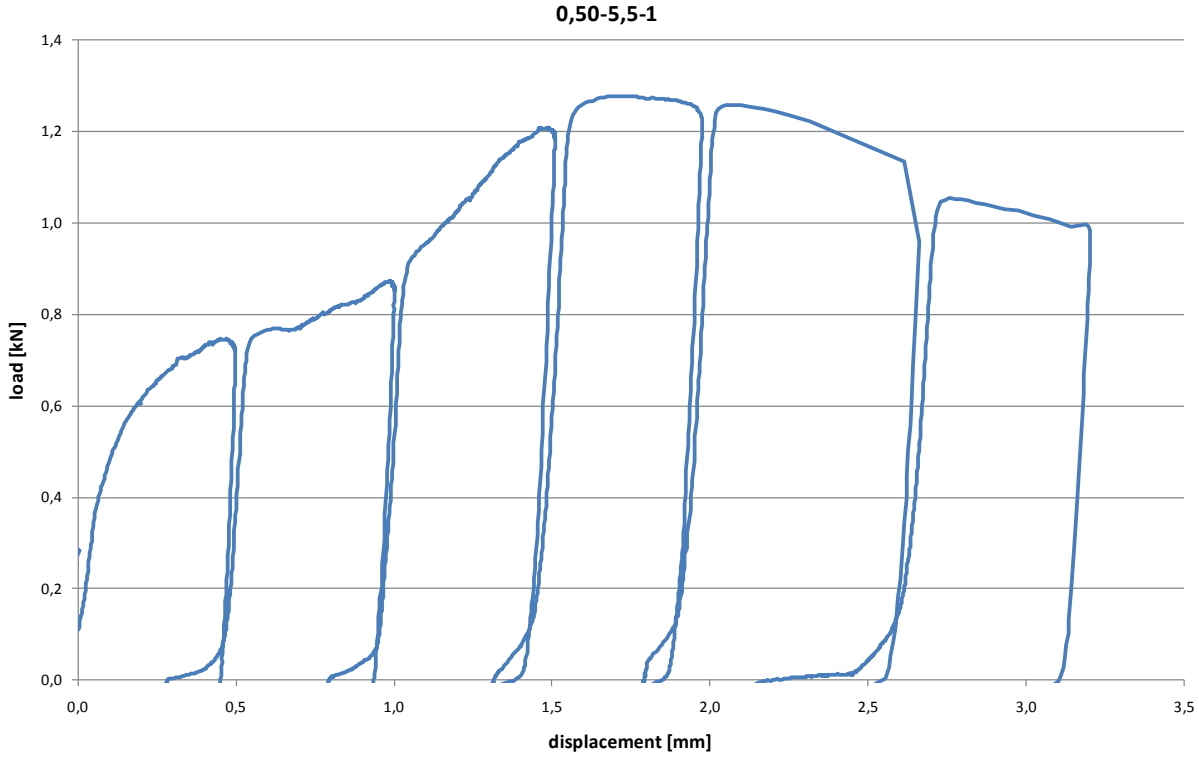


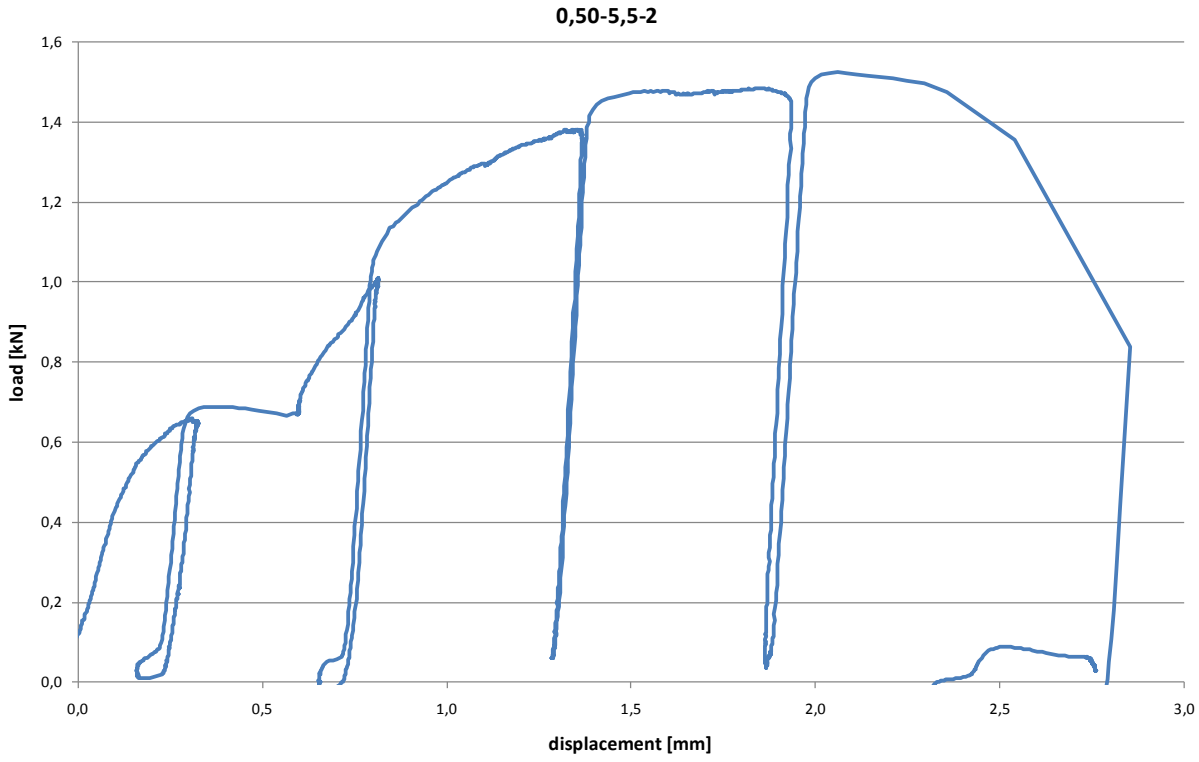

0,40-8,0-3
load [kN]
displacement [mm]
1,2
1,0
0,8
0,6
0,4
0,2
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5

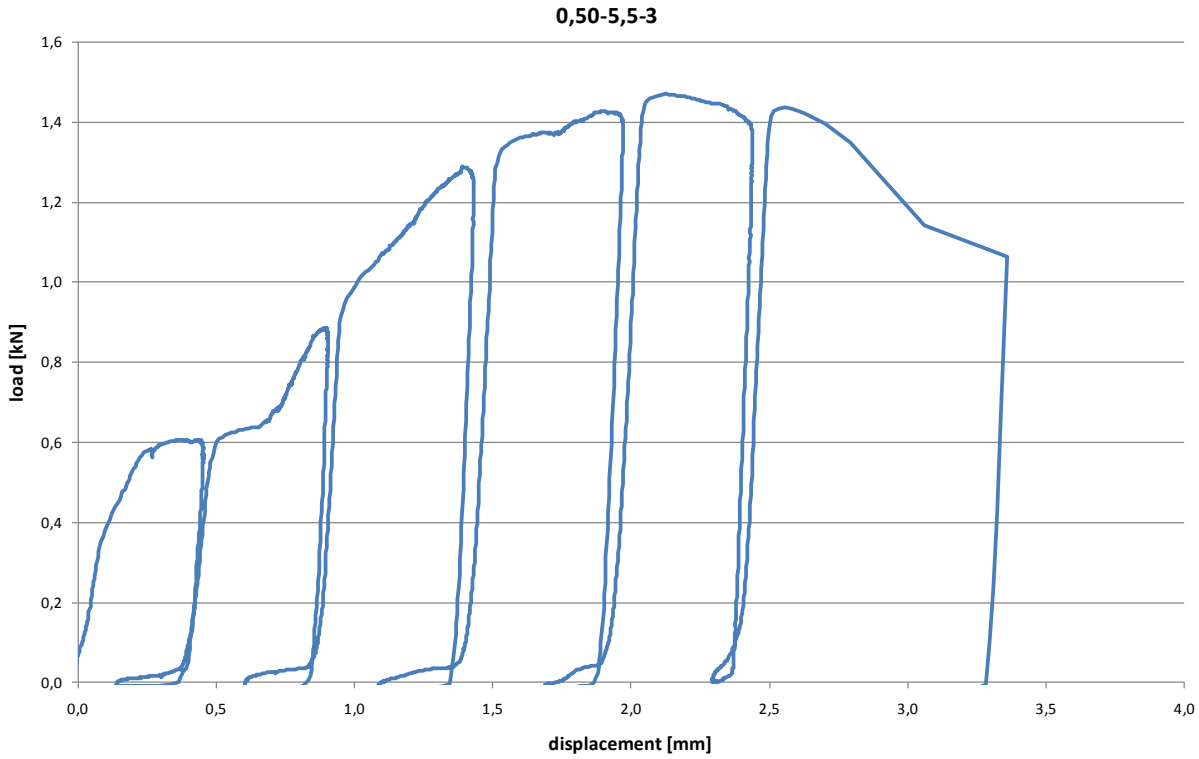
Hole elongation tests

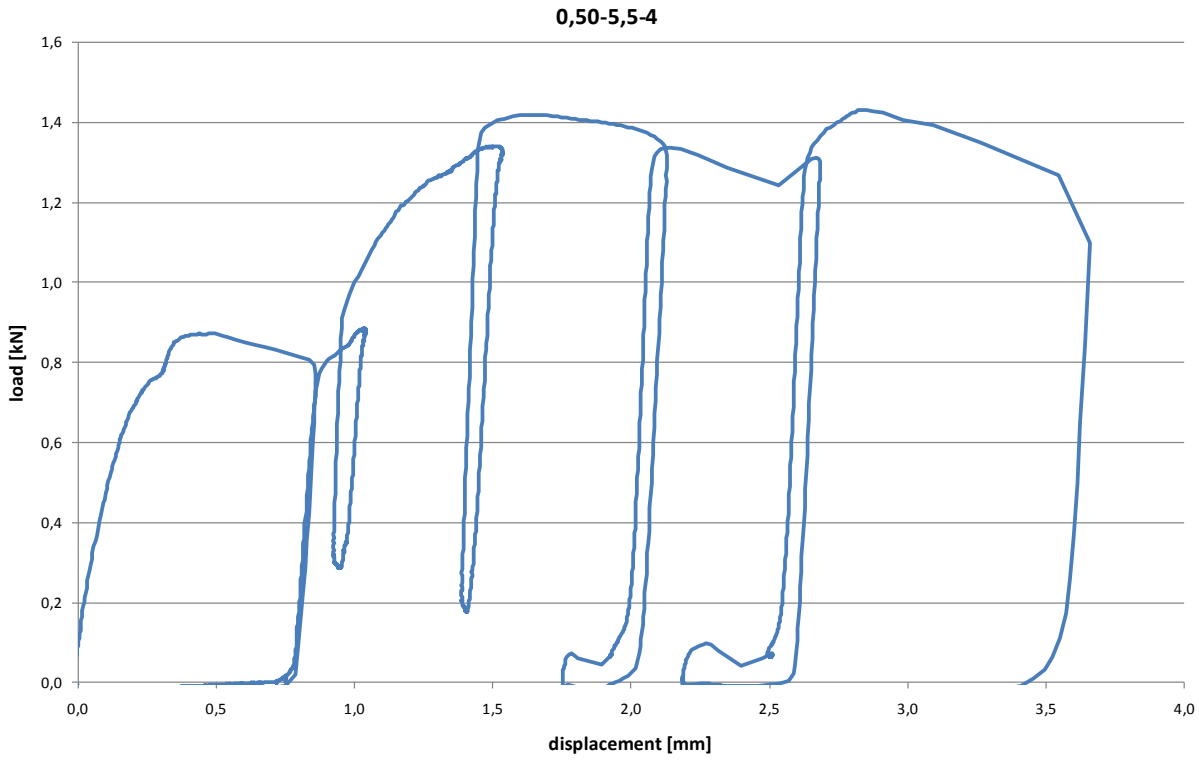
thickness of steel sheet: 0,50 mm

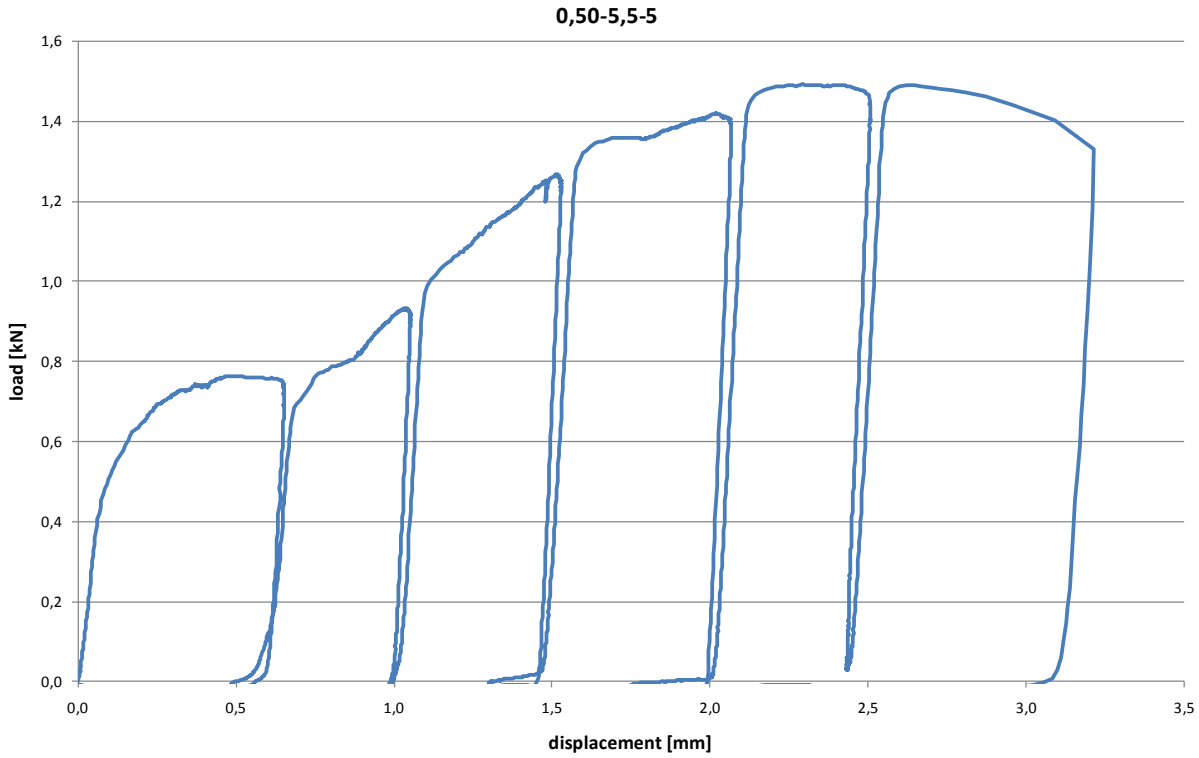
nominal diameter of fastener: 5,5 mm






0,50-5,5-3
load [kN]
displacement [mm]
0,0
0,2
0,4
0,6
0,8
1,0
1,2
1,4
1,6
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0

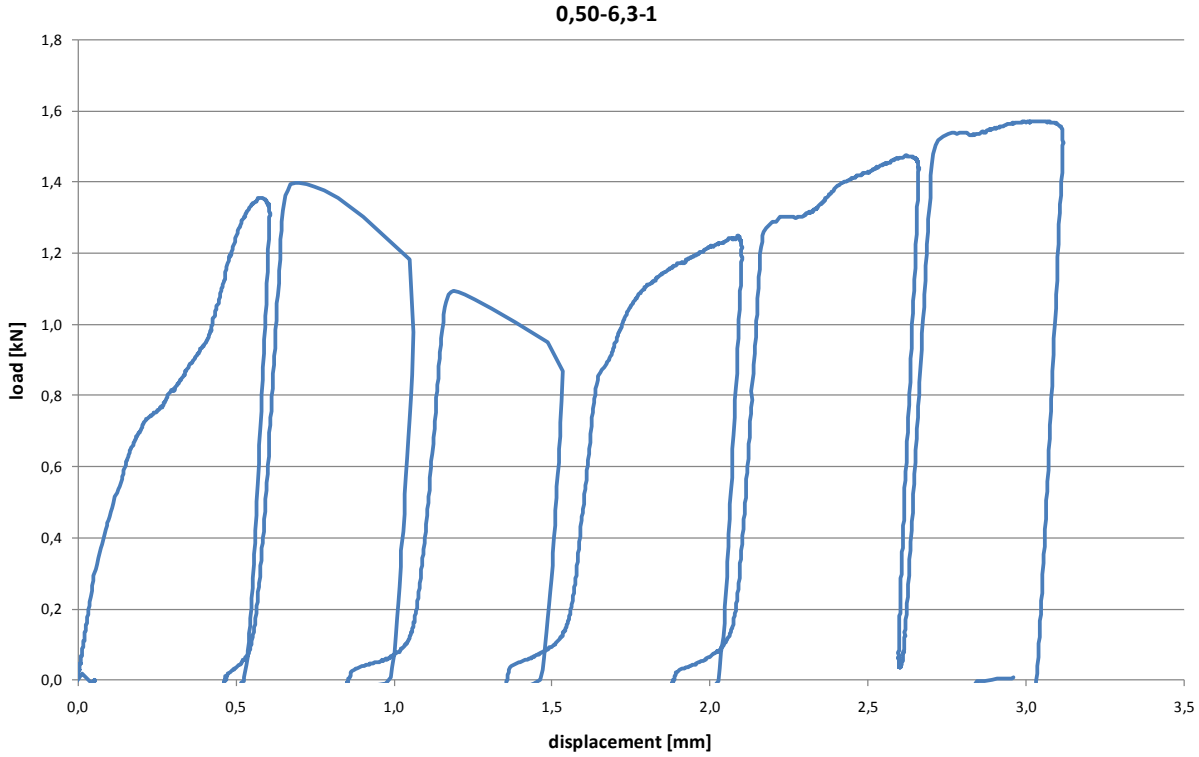

0,50-5,5-4
load [kN]
displacement [mm]
0,0
0,2
0,4
0,6
0,8
1,0
1,2
1,4
1,6
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0

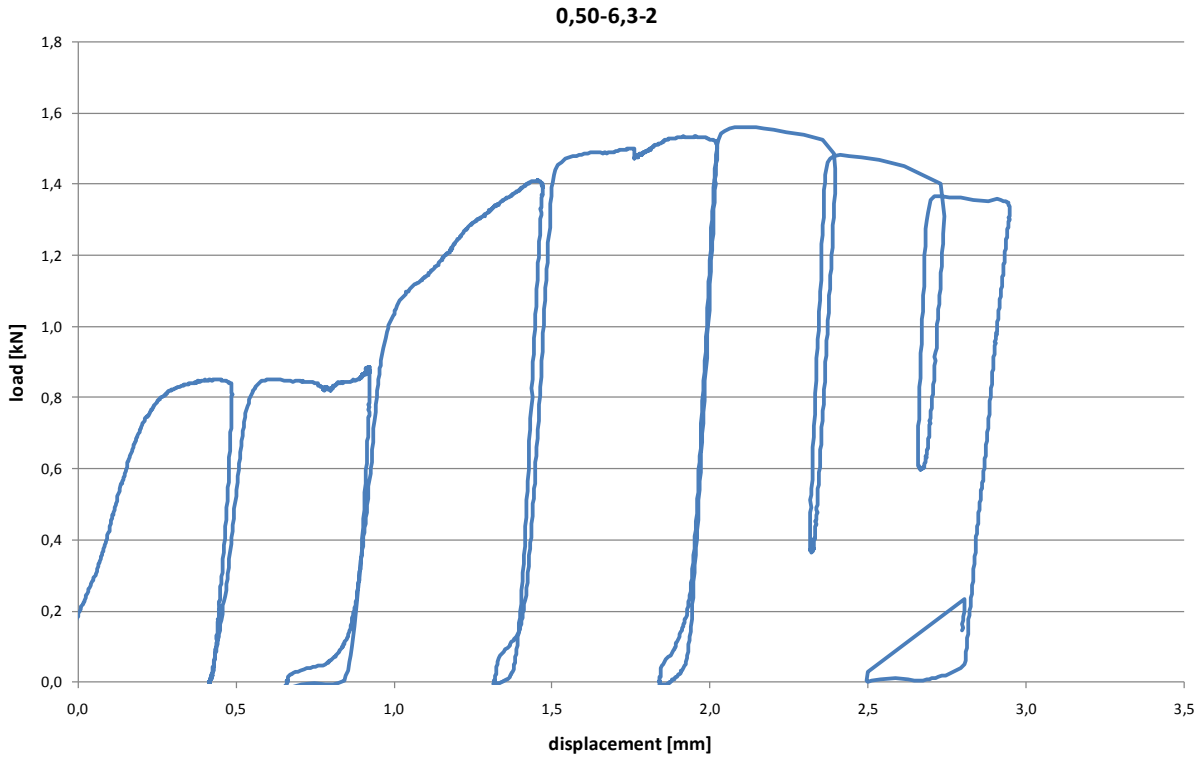

0,50-5,5-5
load [kN]
displacement [mm]
1,6
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5

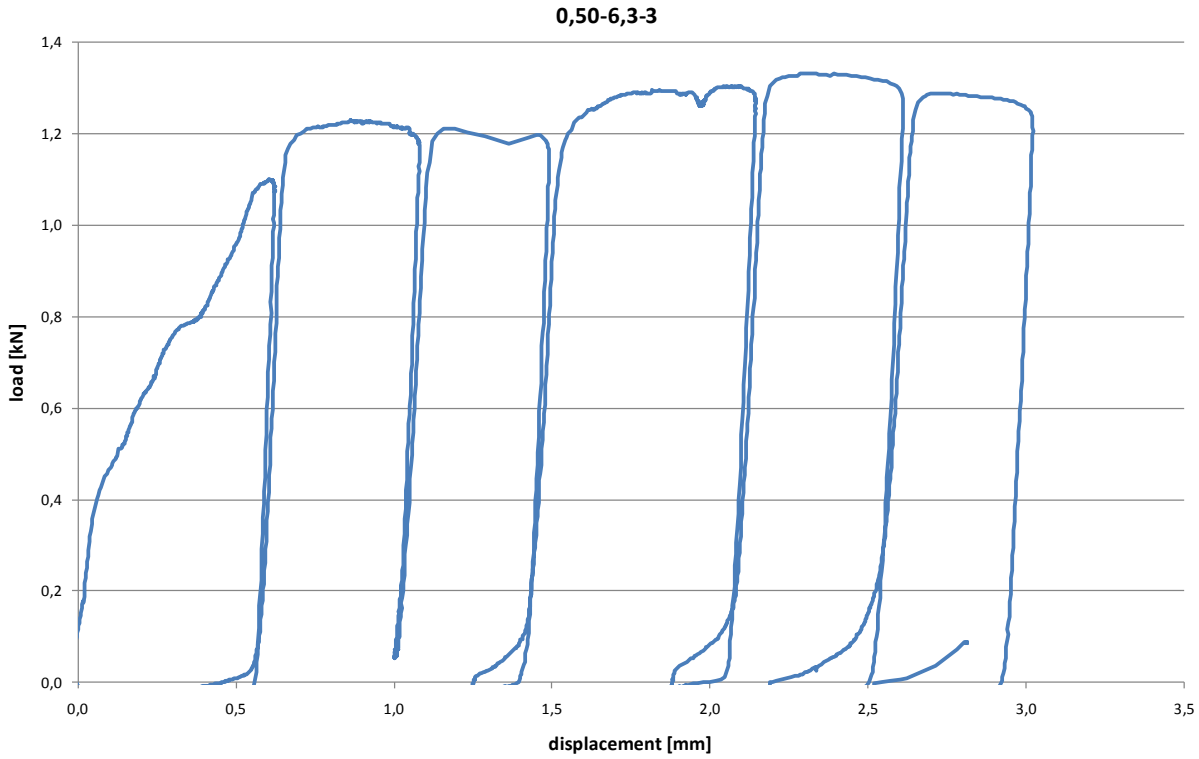
Hole elongation tests

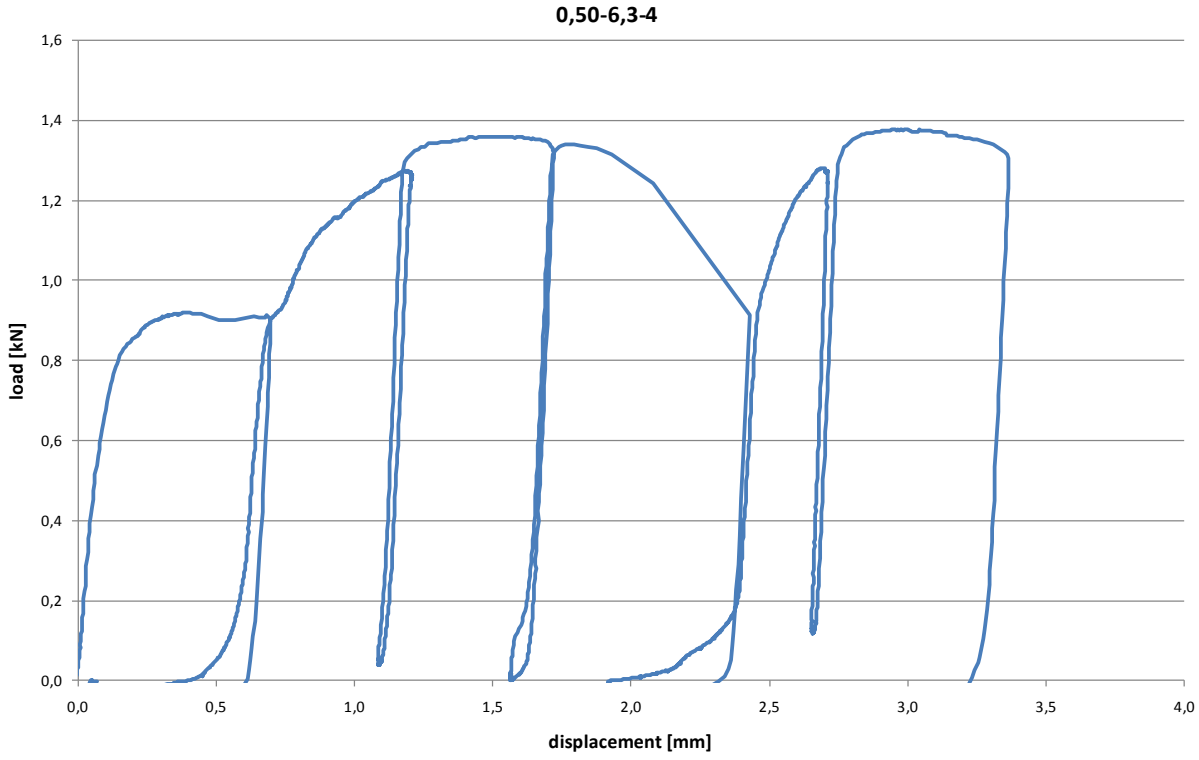
thickness of steel sheet: 0,50 mm

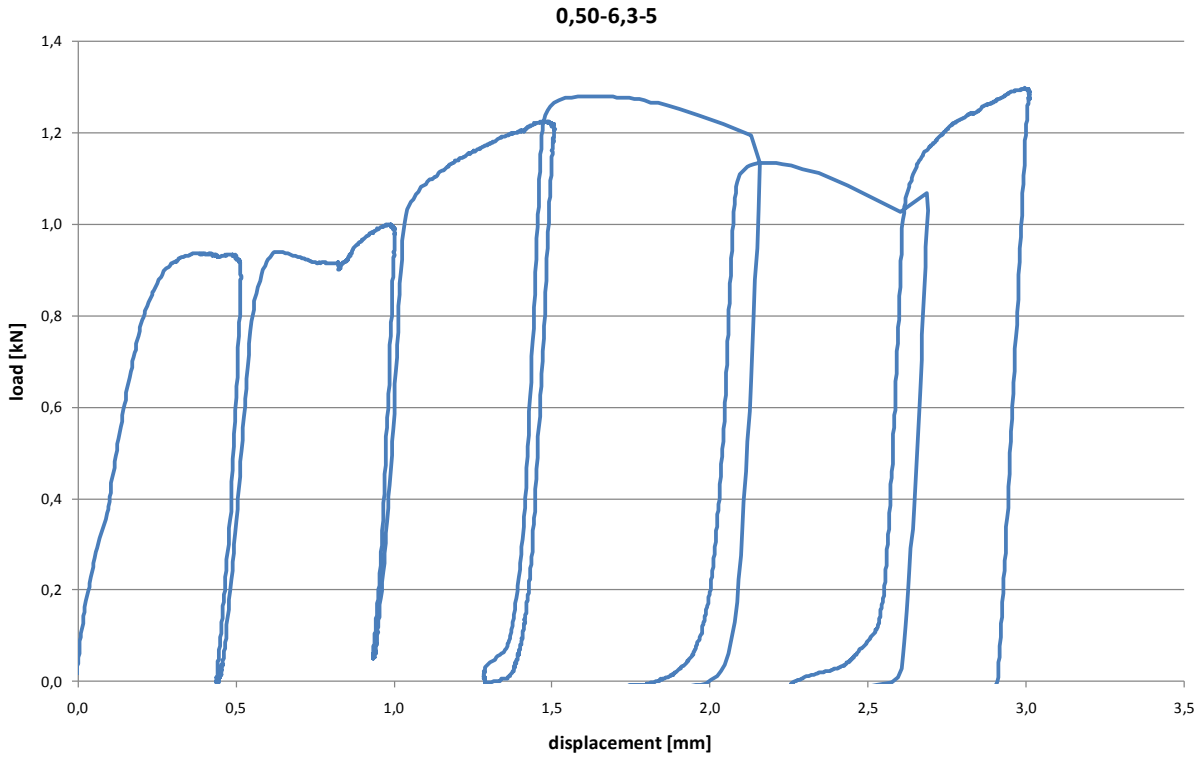
nominal diameter of fastener: 6,3 mm






0,50-6,3-3
load [kN]
displacement [mm]
0,0
0,2
0,4
0,6
0,8
1,0
1,2
1,4
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5

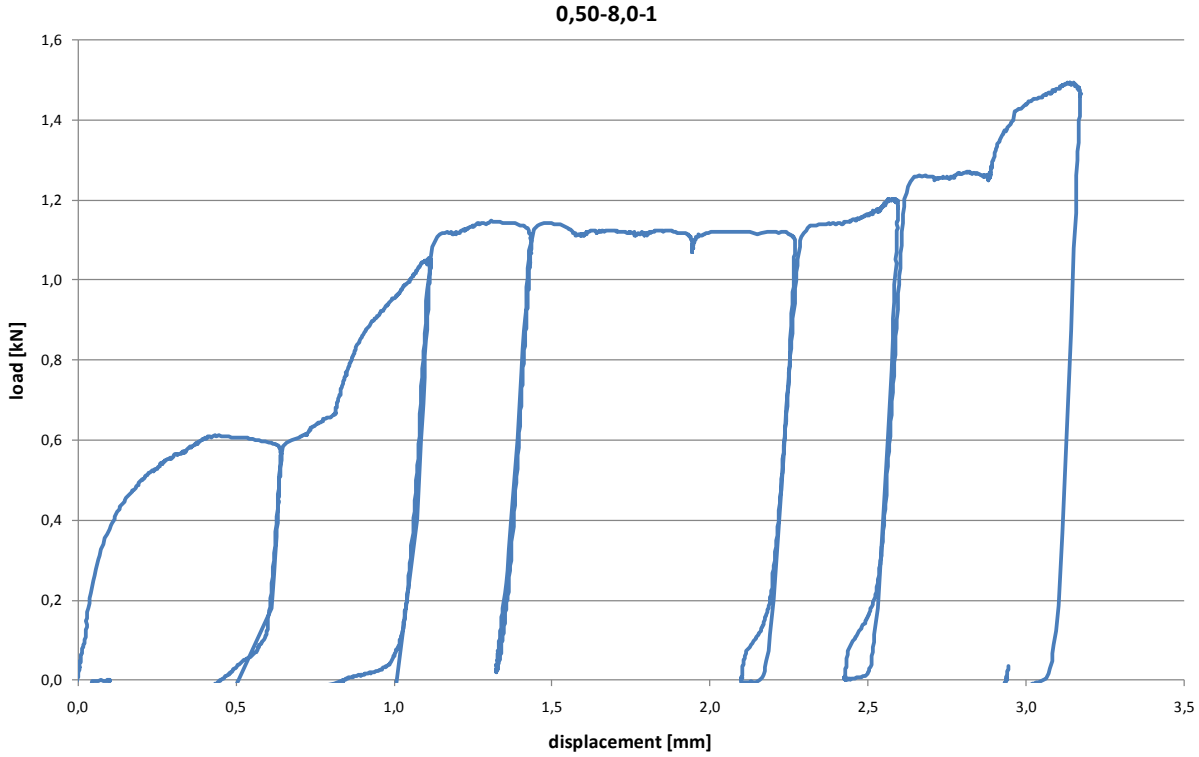

0,50-6,3-4
load [kN]
displacement [mm]
0,0
0,2
0,4
0,6
0,8
1,0
1,2
1,4
1,6
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0

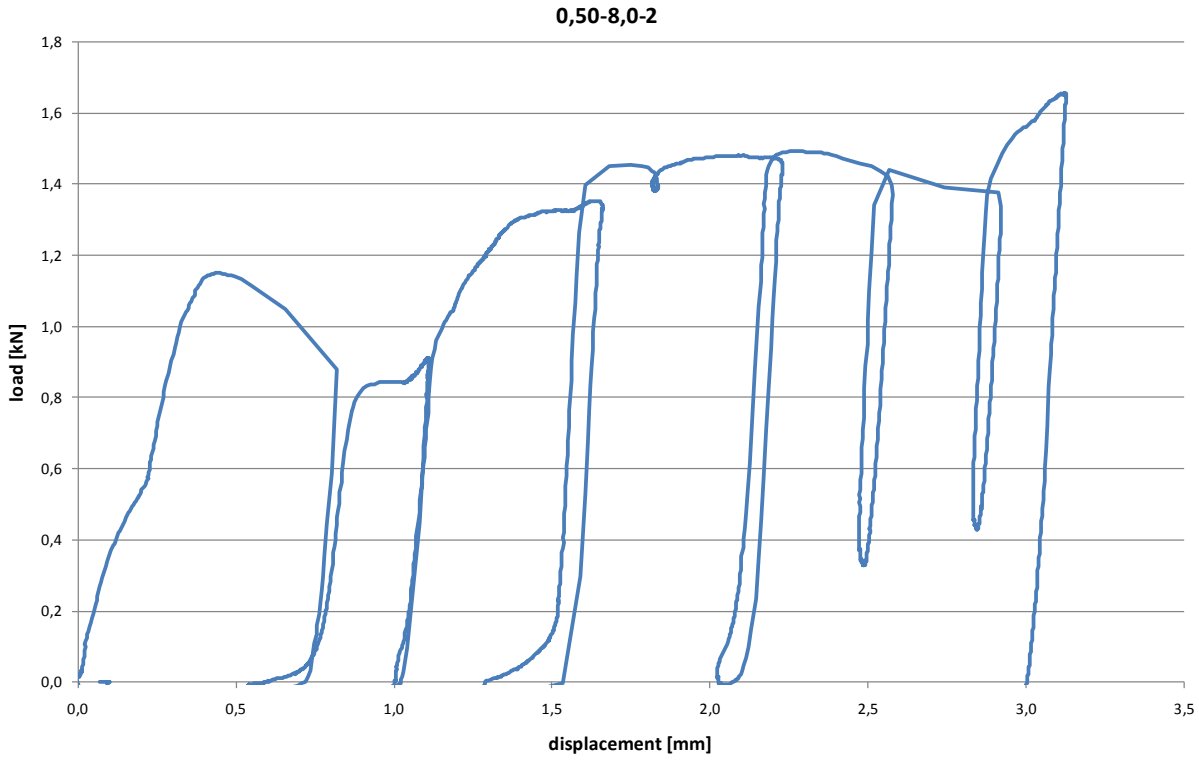

0,50-6,3-5
load [kN]
displacement [mm]
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5

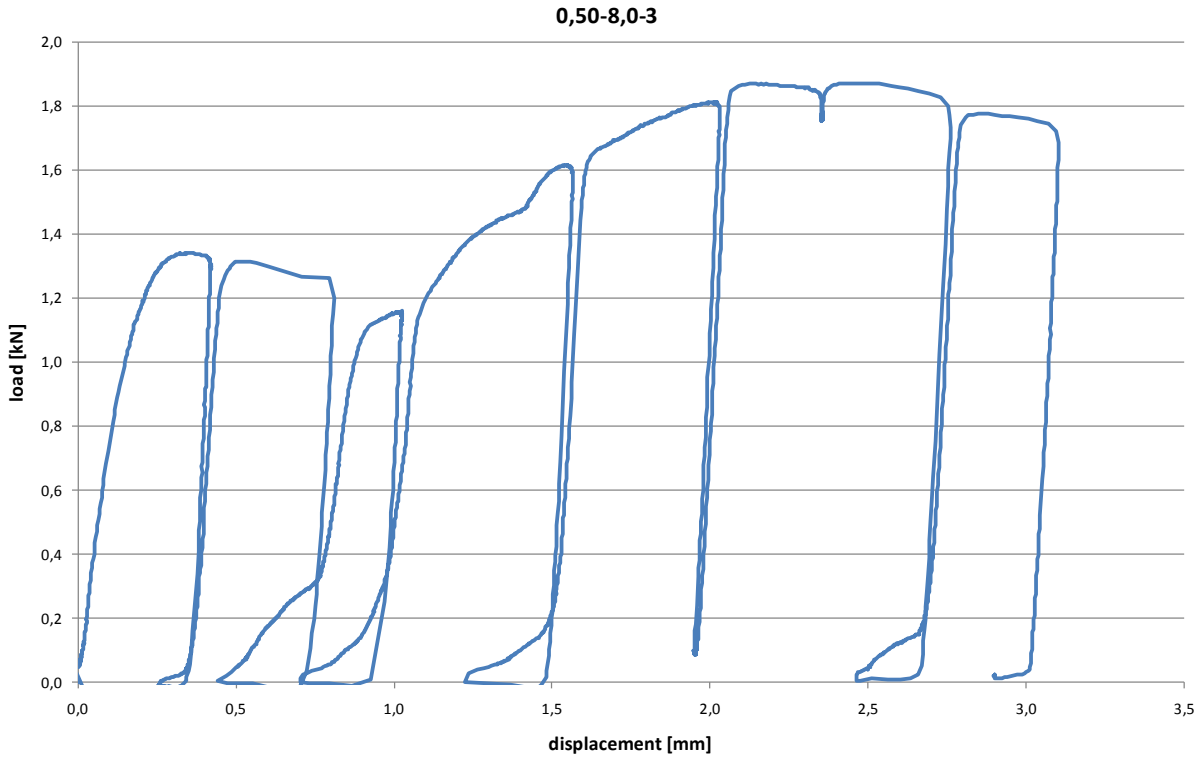
Hole elongation tests

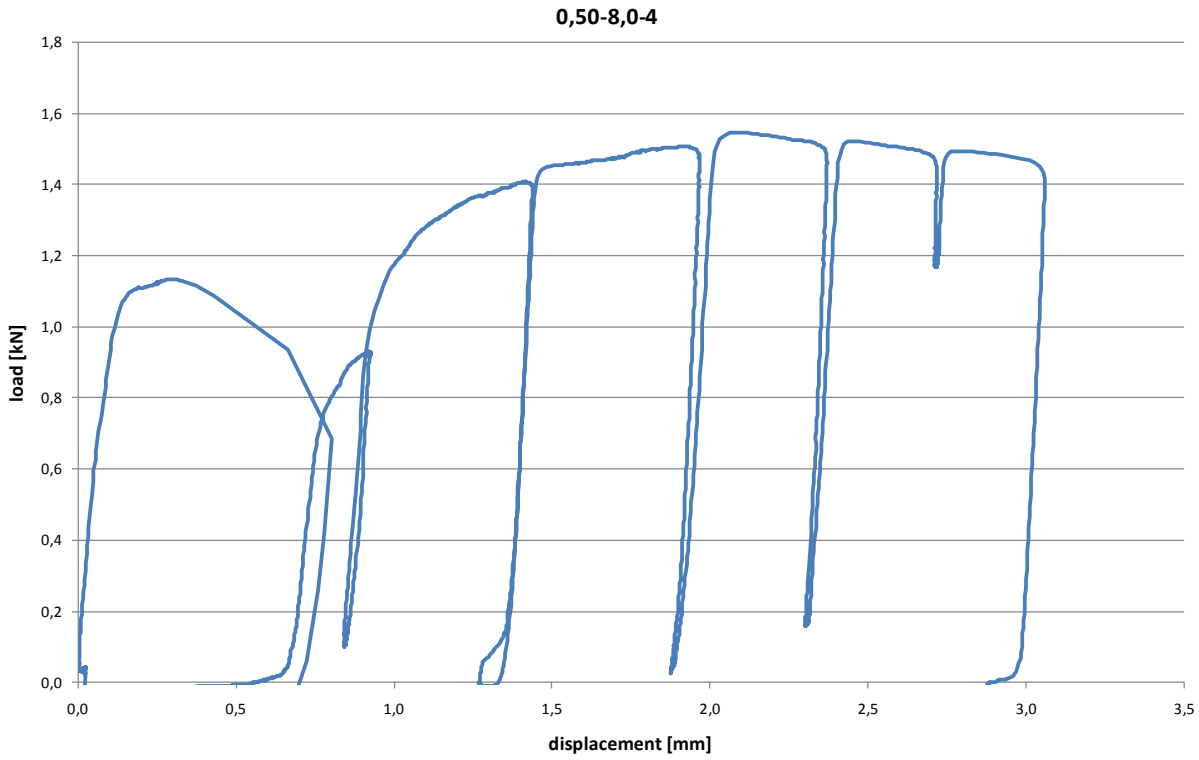
thickness of steel sheet: 0,50 mm

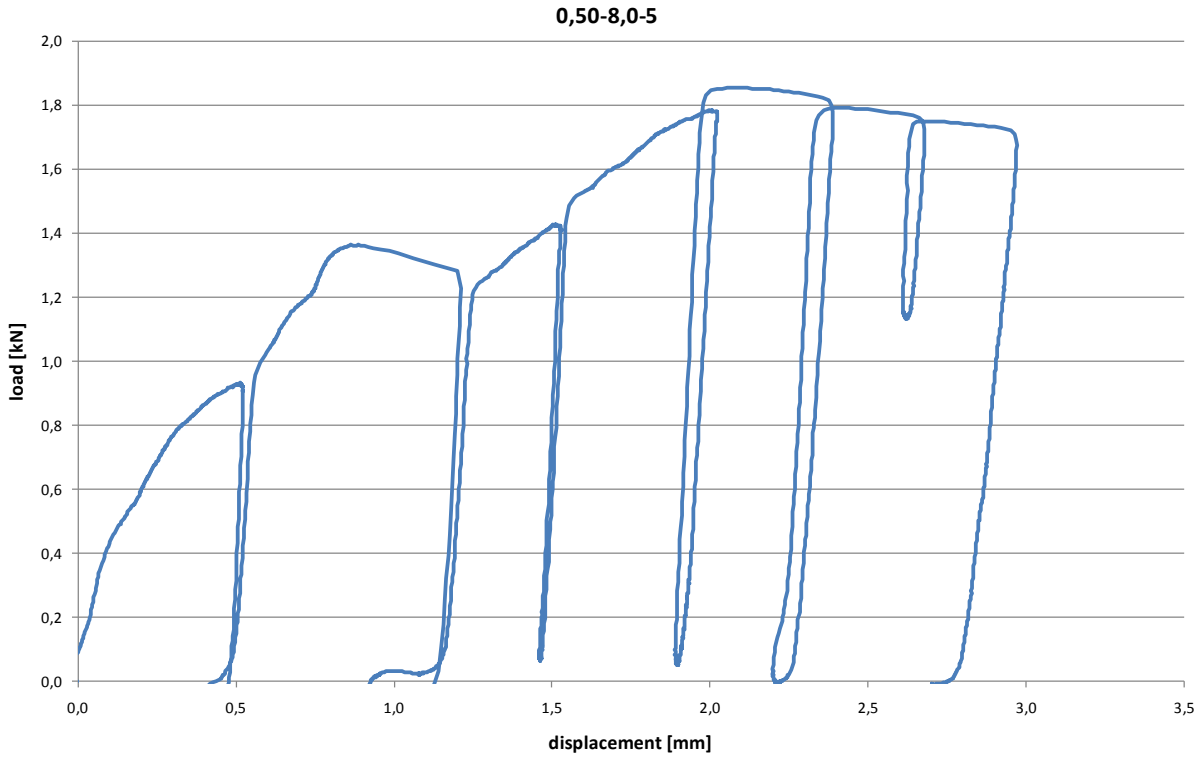
nominal diameter of fastener: 8,0 mm






0,50-8,0-3
load [kN]
displacement [mm]
2,0
1,8
1,6
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5

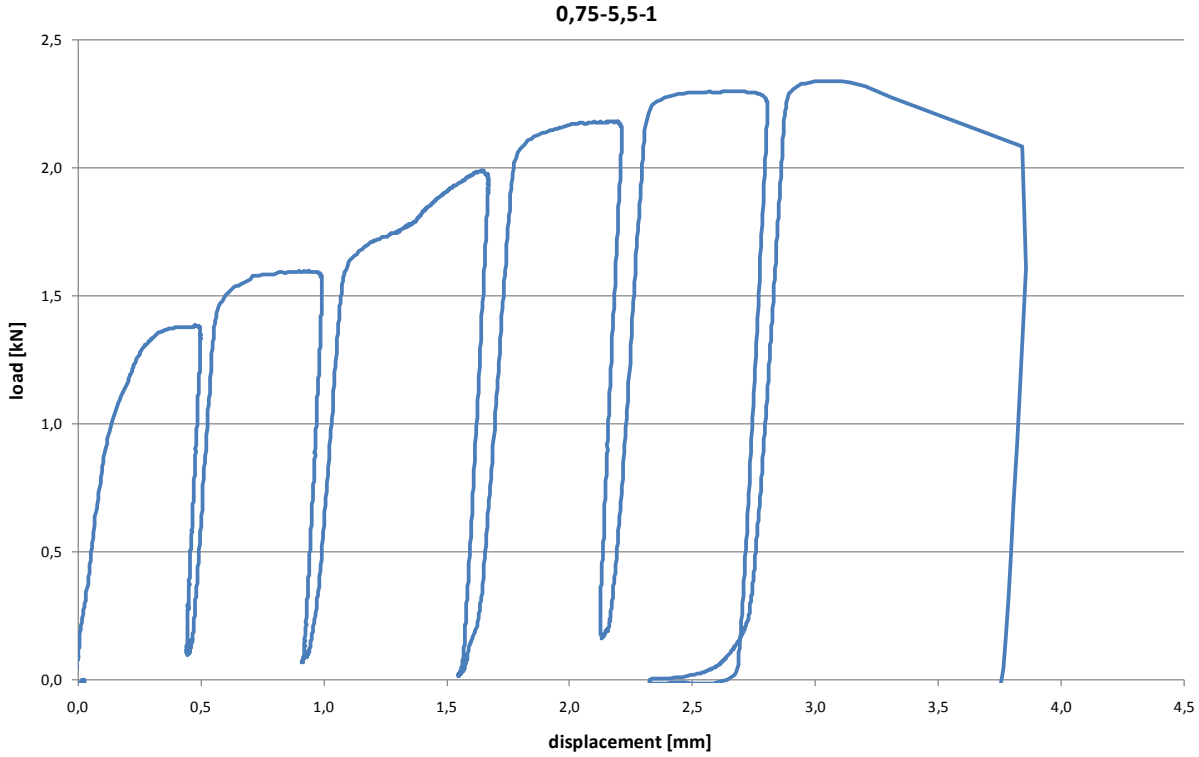

0,50-8,0-4
load [kN]
displacement [mm]
1,8
1,6
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5

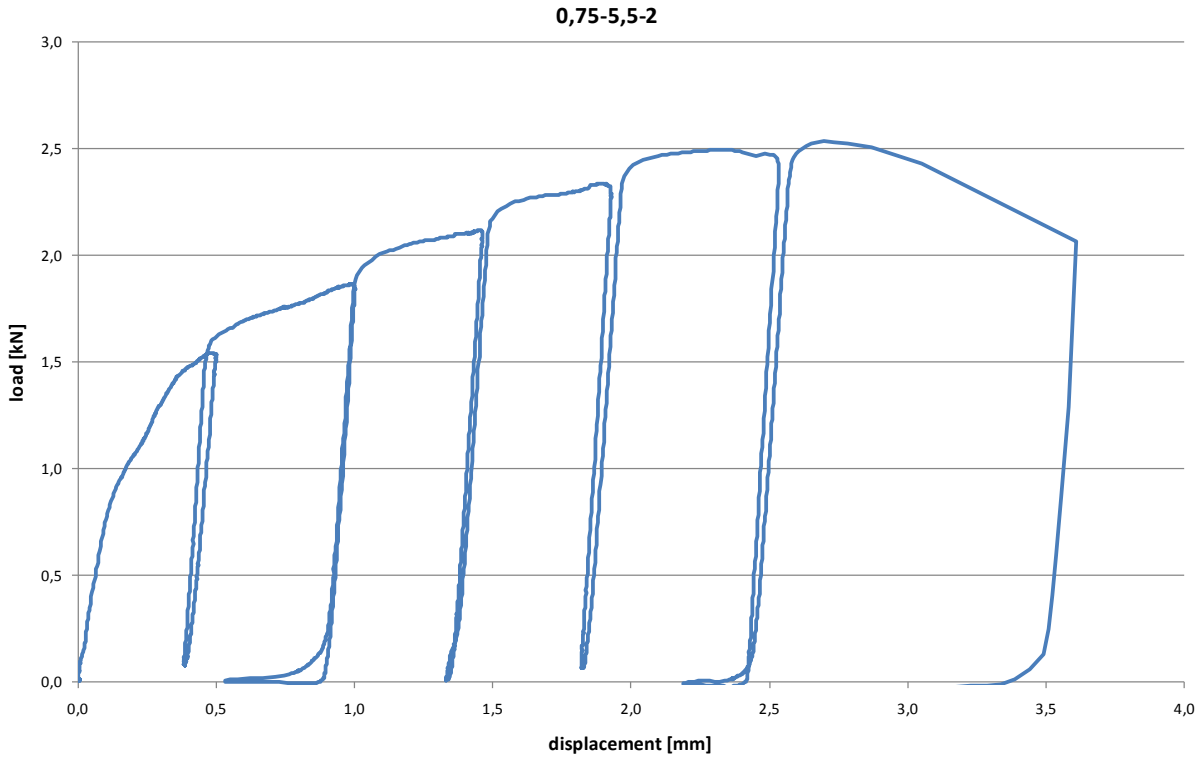

0,50-8,0-5
load [kN]
displacement [mm]
2,0
1,8
1,6
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5

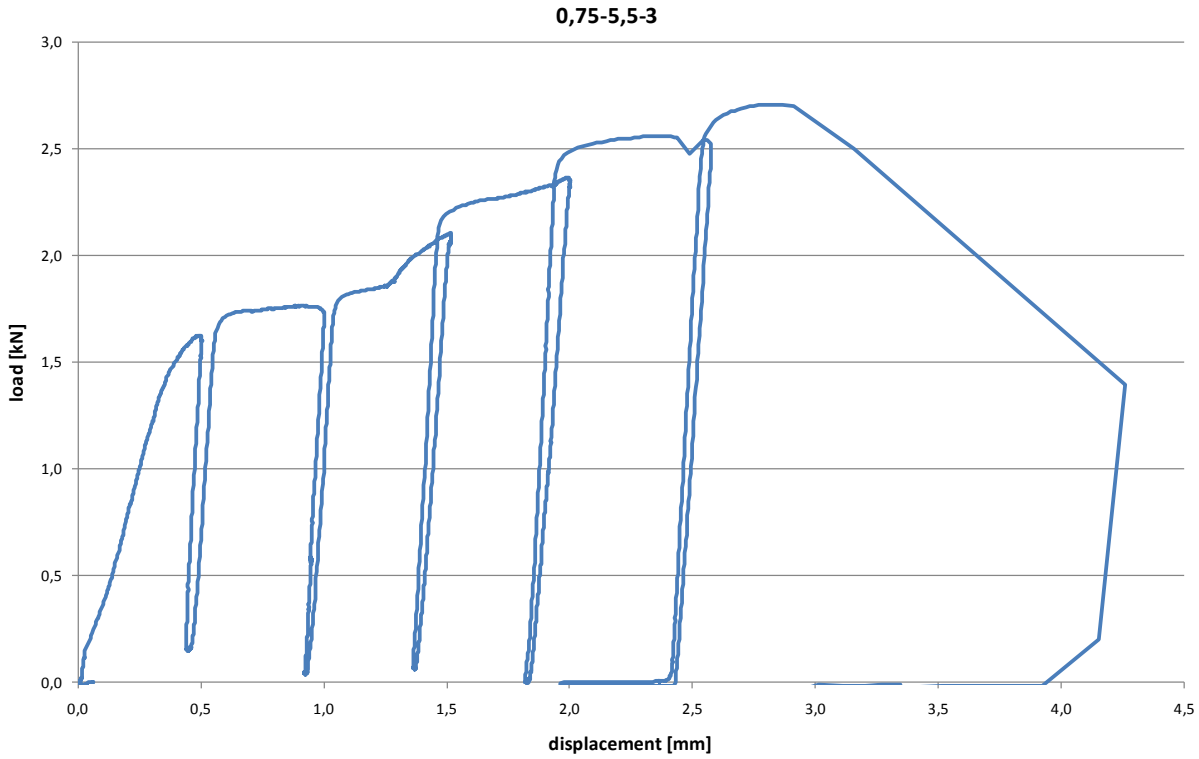
Hole elongation tests

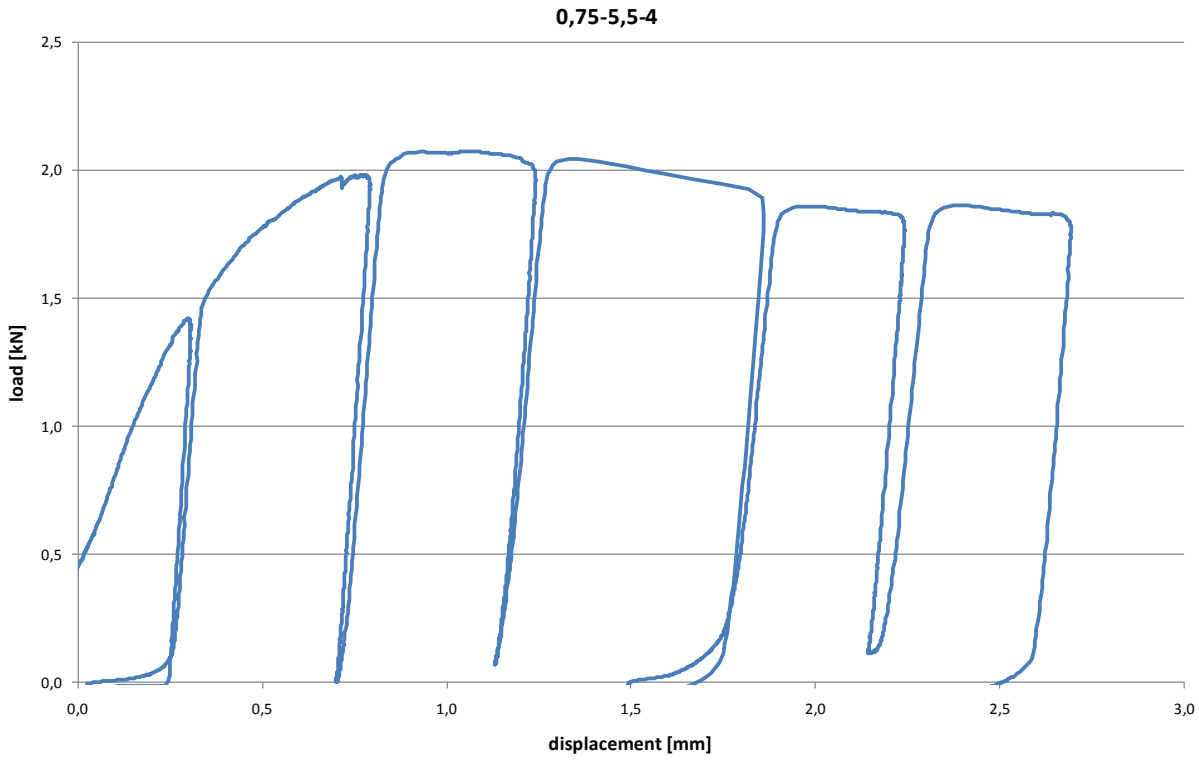
thickness of steel sheet: 0,75 mm

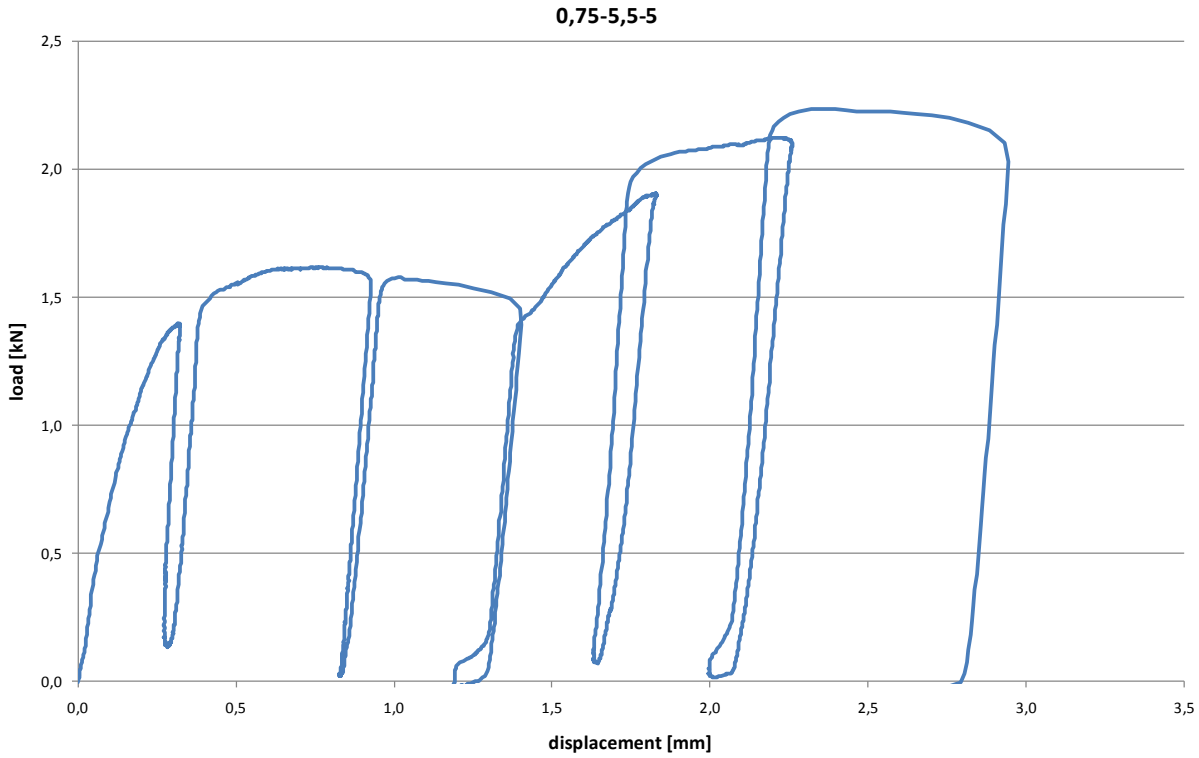
nominal diameter of fastener: 5,5 mm






0,75-5,5-3
load [kN]
displacement [mm]
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
4,5

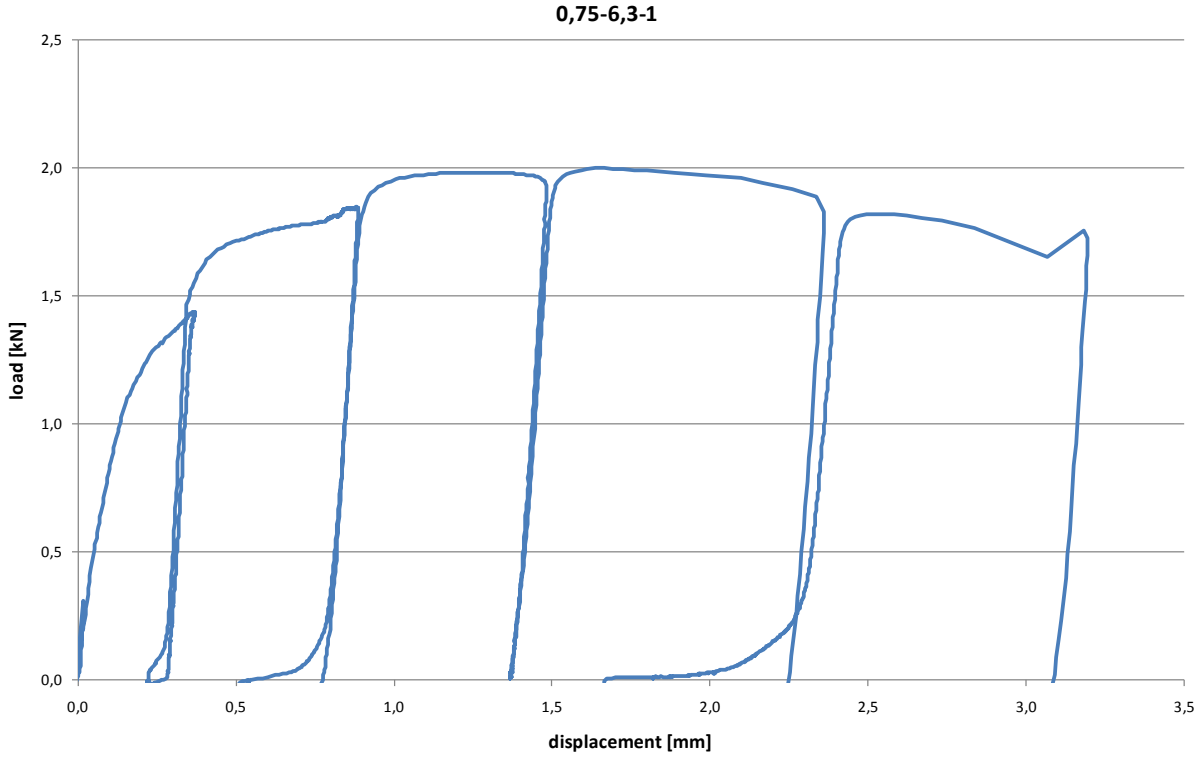

0,75-5,5-4
load [kN]
displacement [mm]
2,5
2,0
1,5
1,0
0,5
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0

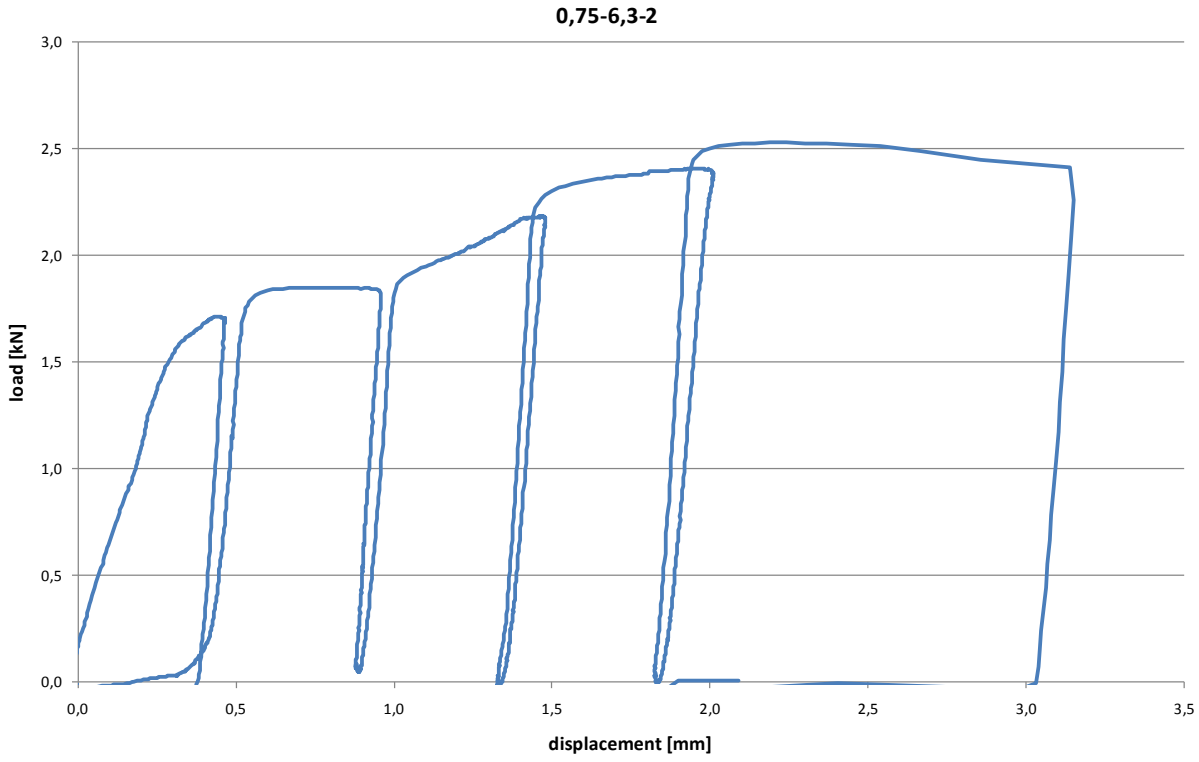

0,75-5,5-5
load [kN]
displacement [mm]
2,5
2,0
1,5
1,0
0,5
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5

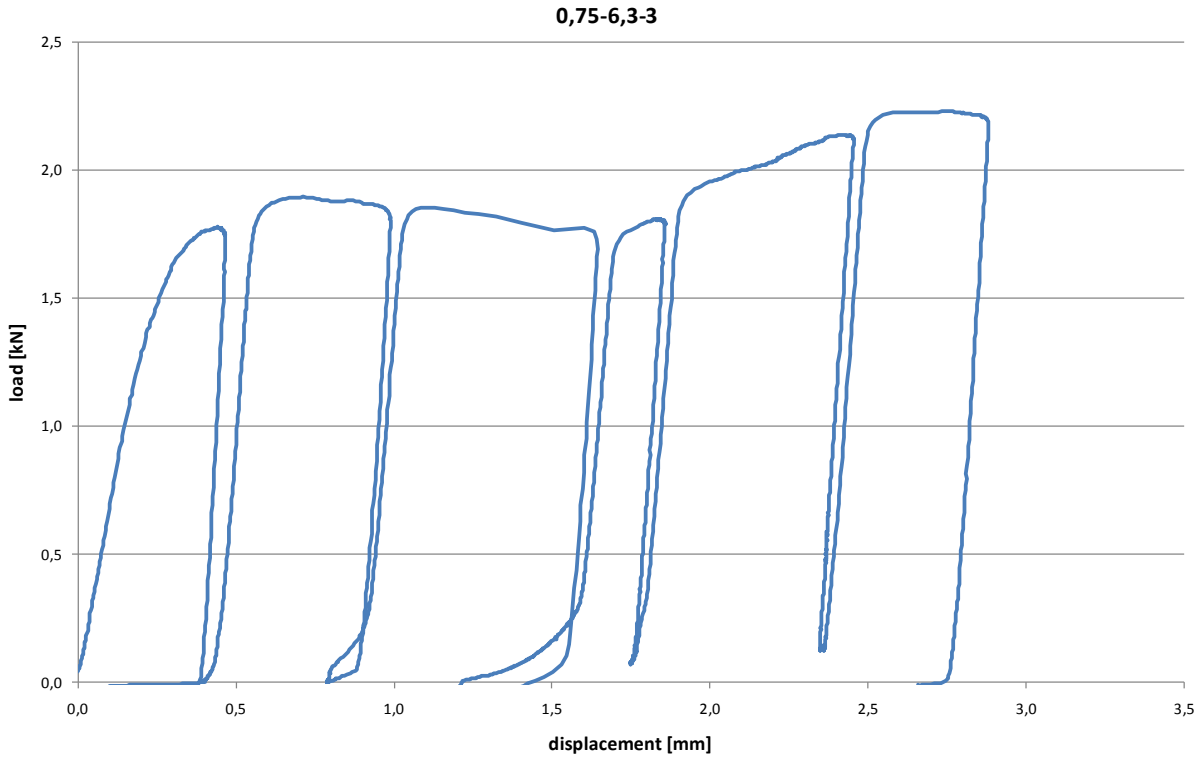
Hole elongation tests

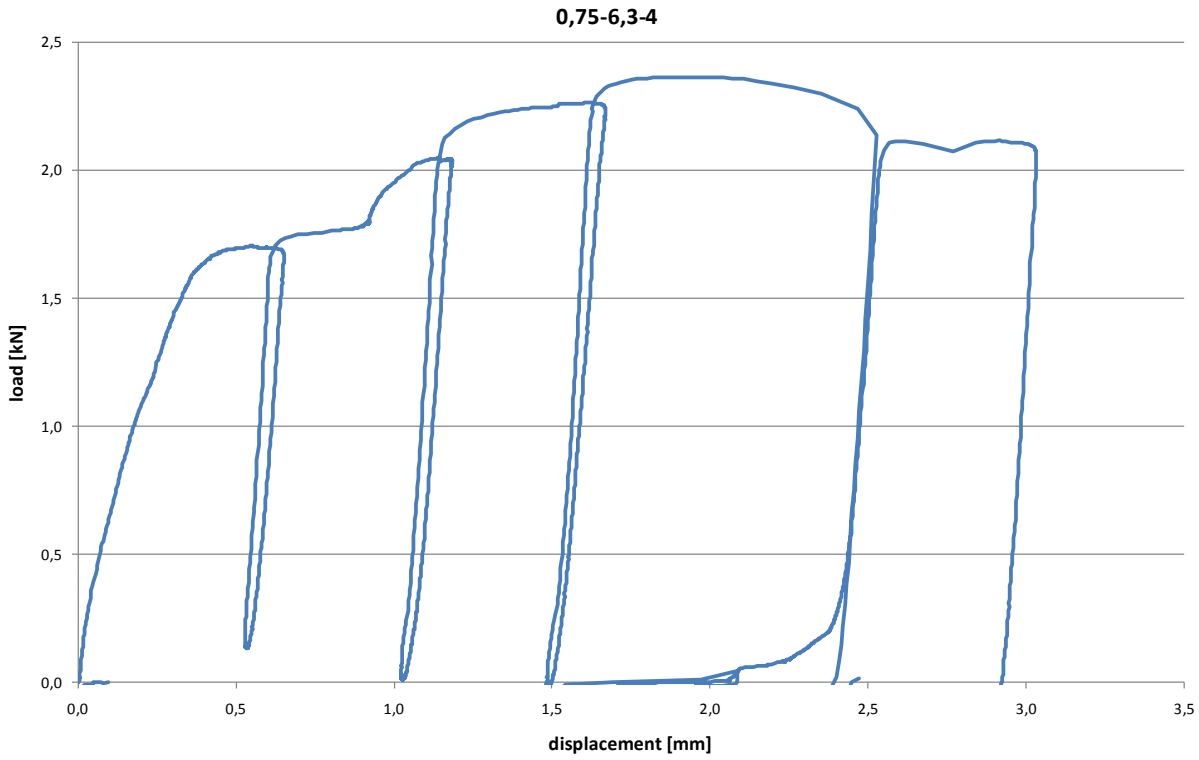
thickness of steel sheet: 0,75 mm

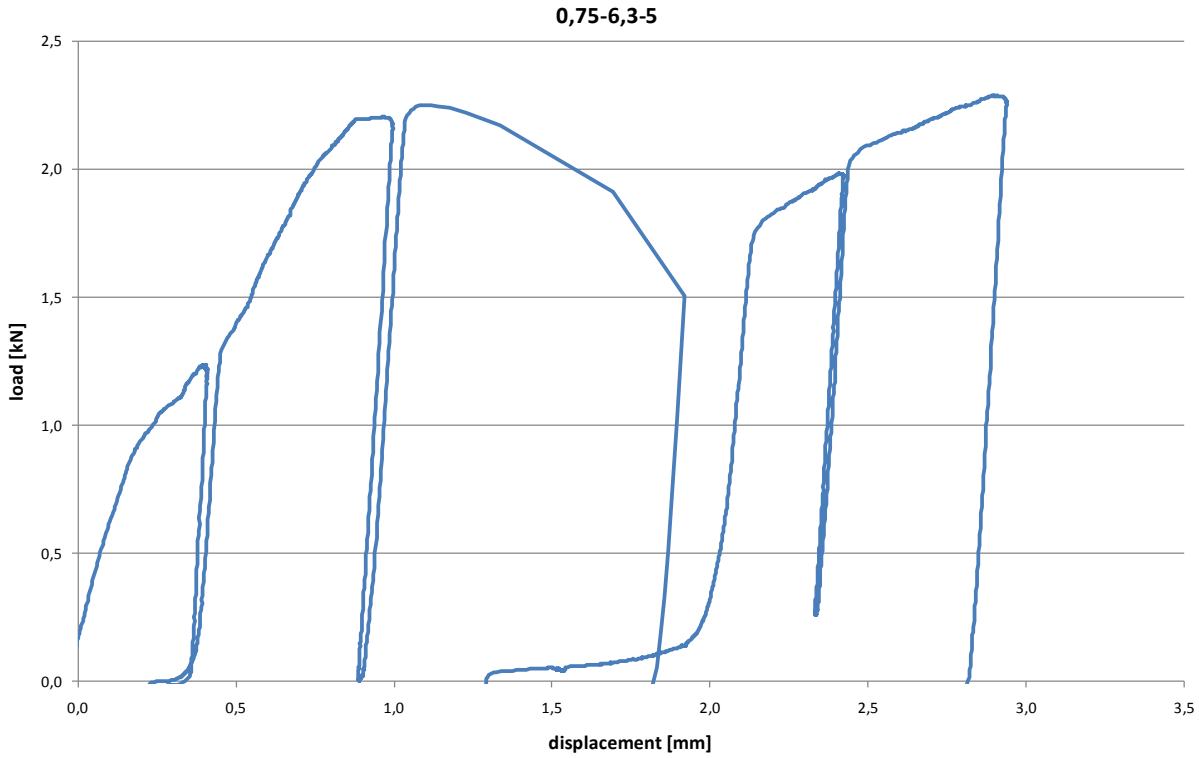
nominal diameter of fastener: 6,3 mm






0,75-6,3-3
load [kN]
displacement [mm]
2,5
2,0
1,5
1,0
0,5
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5

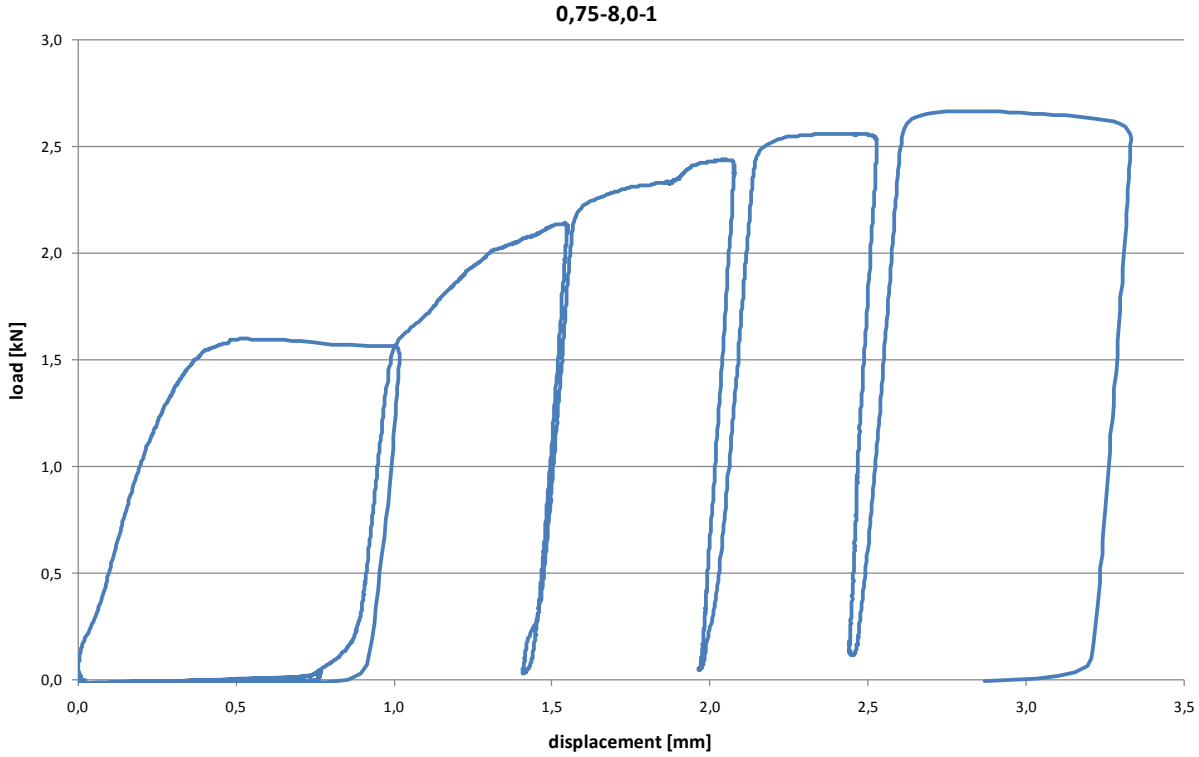

0,75-6,3-4
load [kN]
displacement [mm]
2,5
2,0
1,5
1,0
0,5
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5

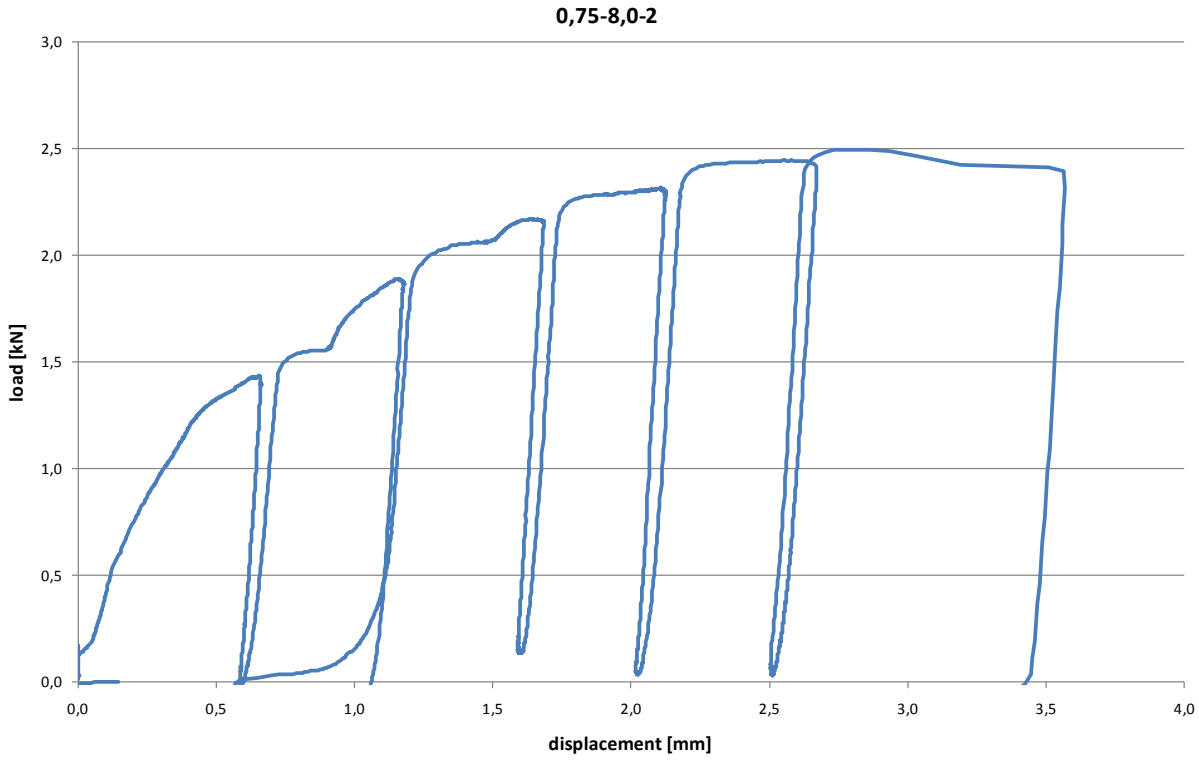

0,75-6,3-5
load [kN]
displacement [mm]
2,5
2,0
1,5
1,0
0,5
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5

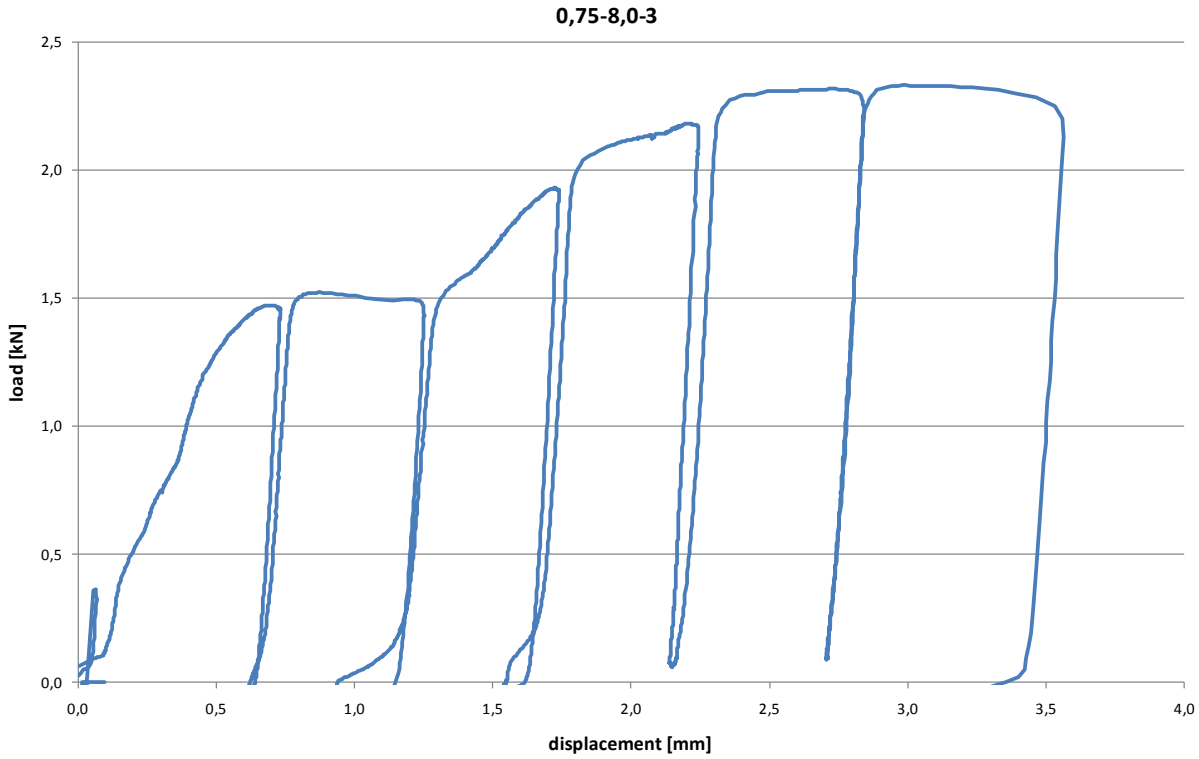
Hole elongation tests

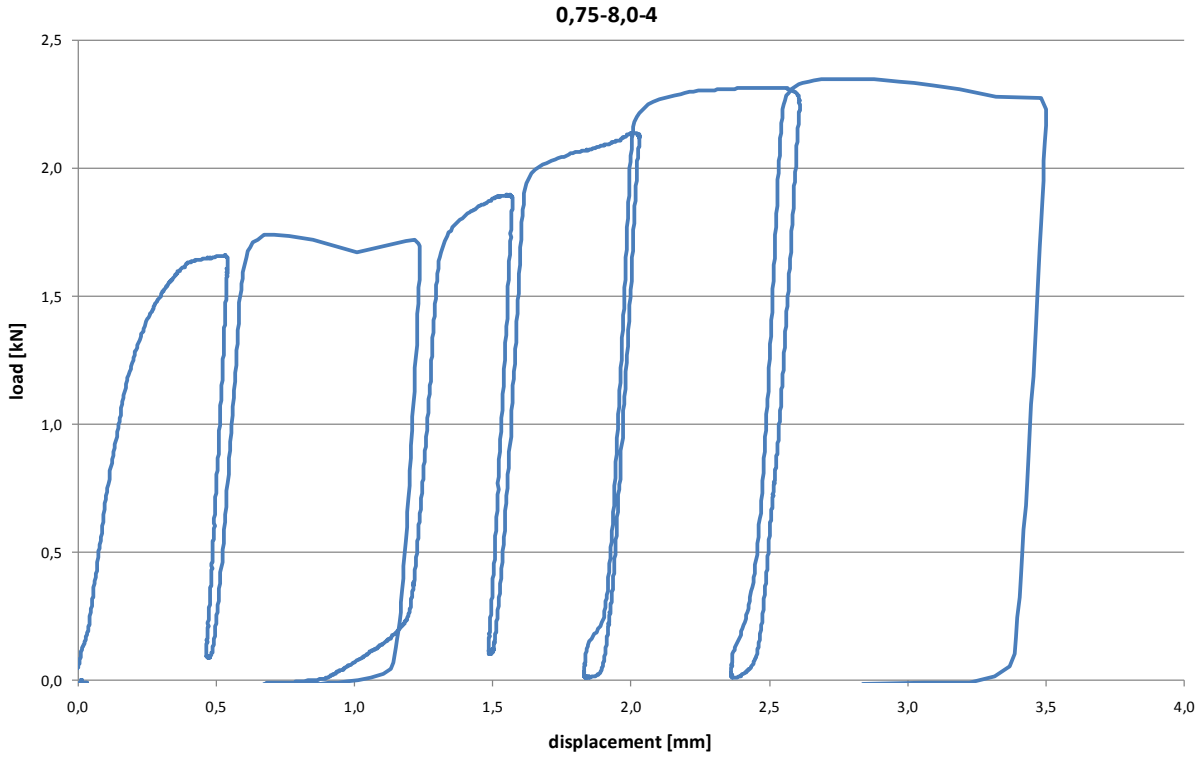
thickness of steel sheet: 0,75 mm

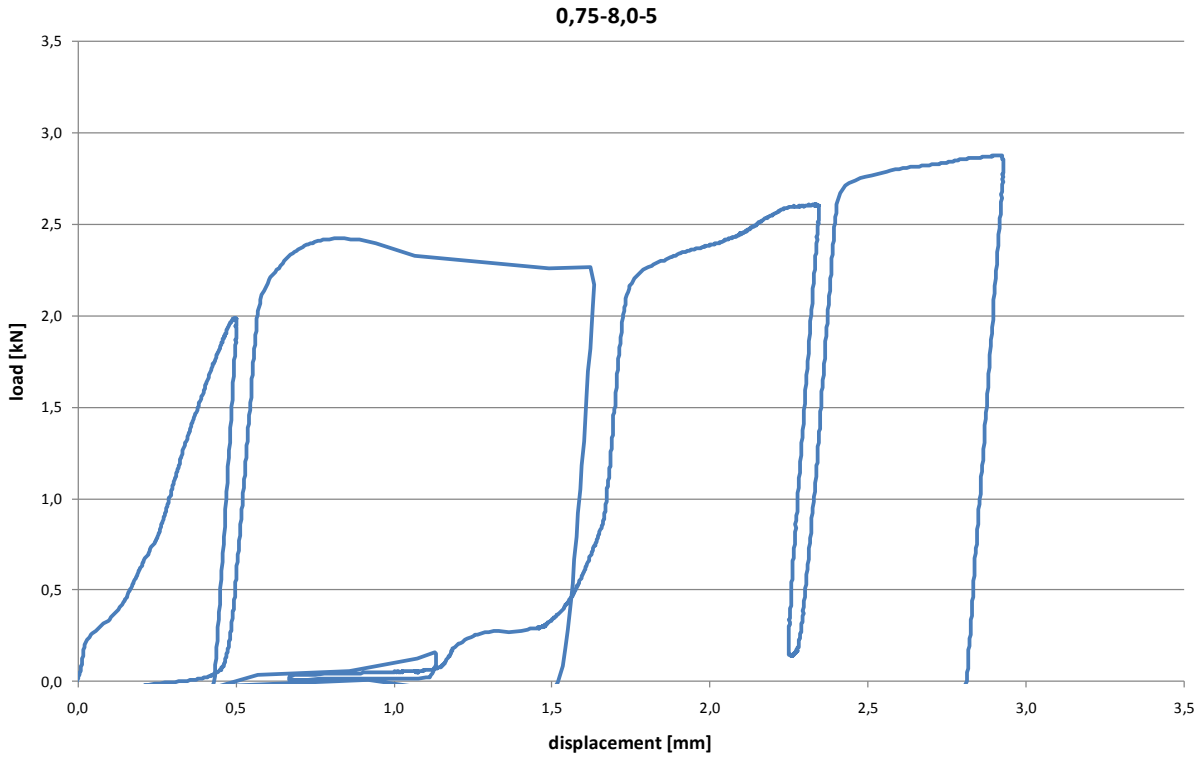
nominal diameter of fastener: 8,0 mm






0,75-8,0-3
load [kN]
displacement [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0

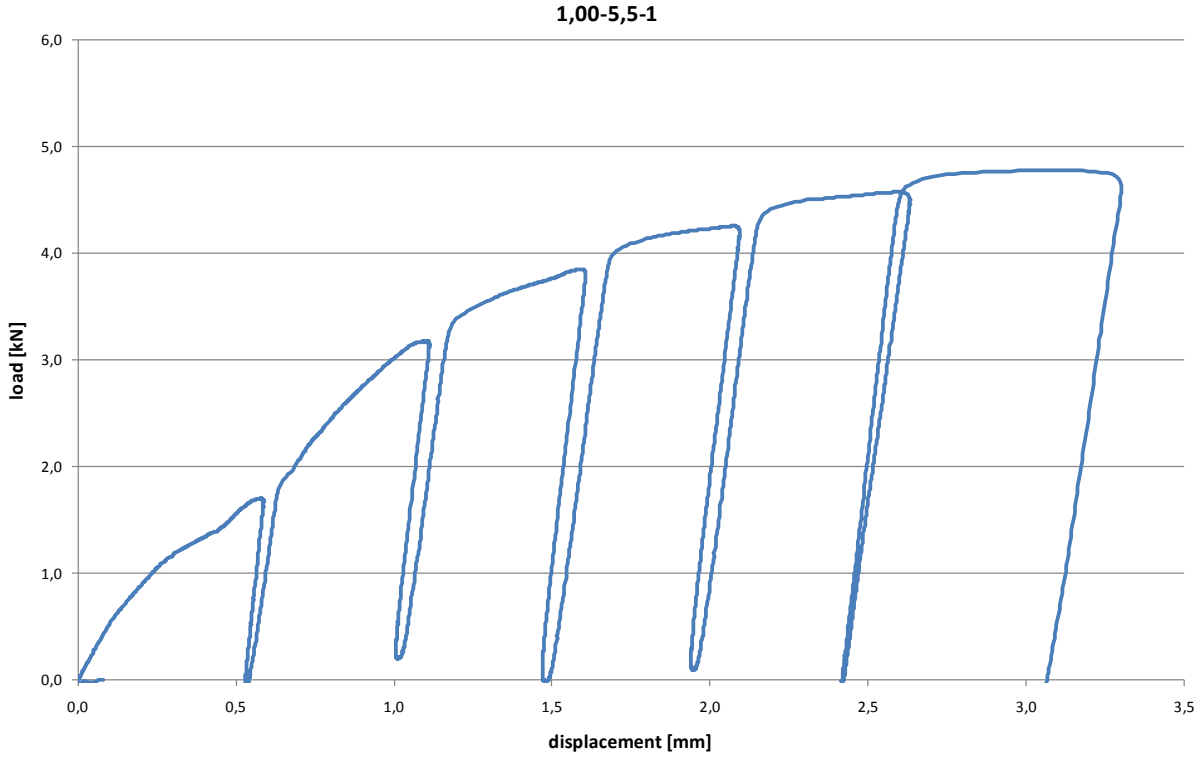

0,75-8,0-4
load [kN]
displacement [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0

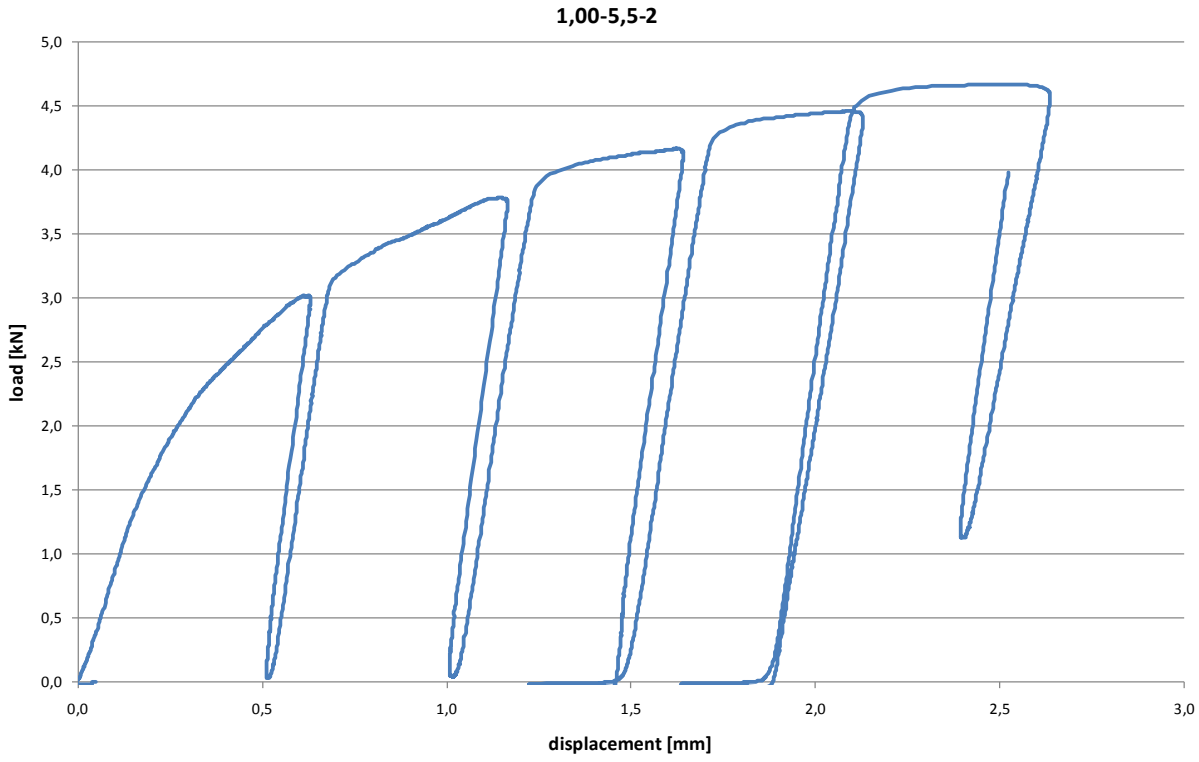

0,75-8,0-5
load [kN]
displacement [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5

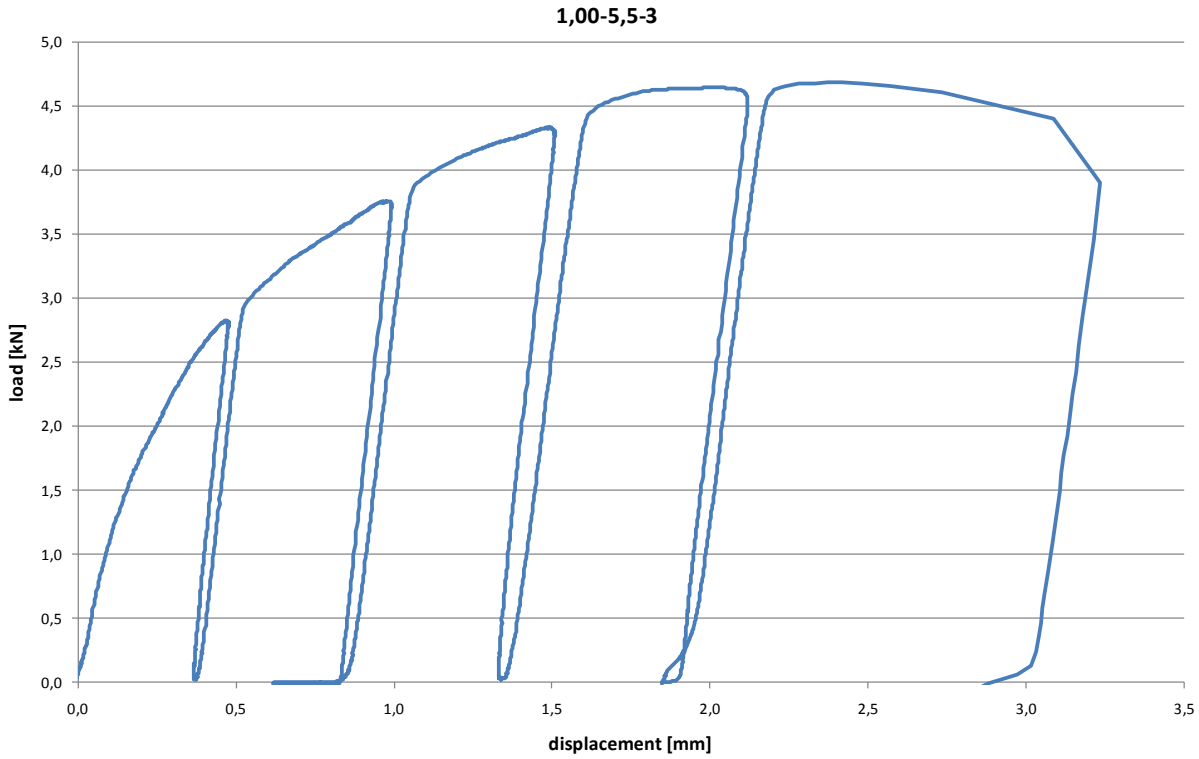
Hole elongation tests

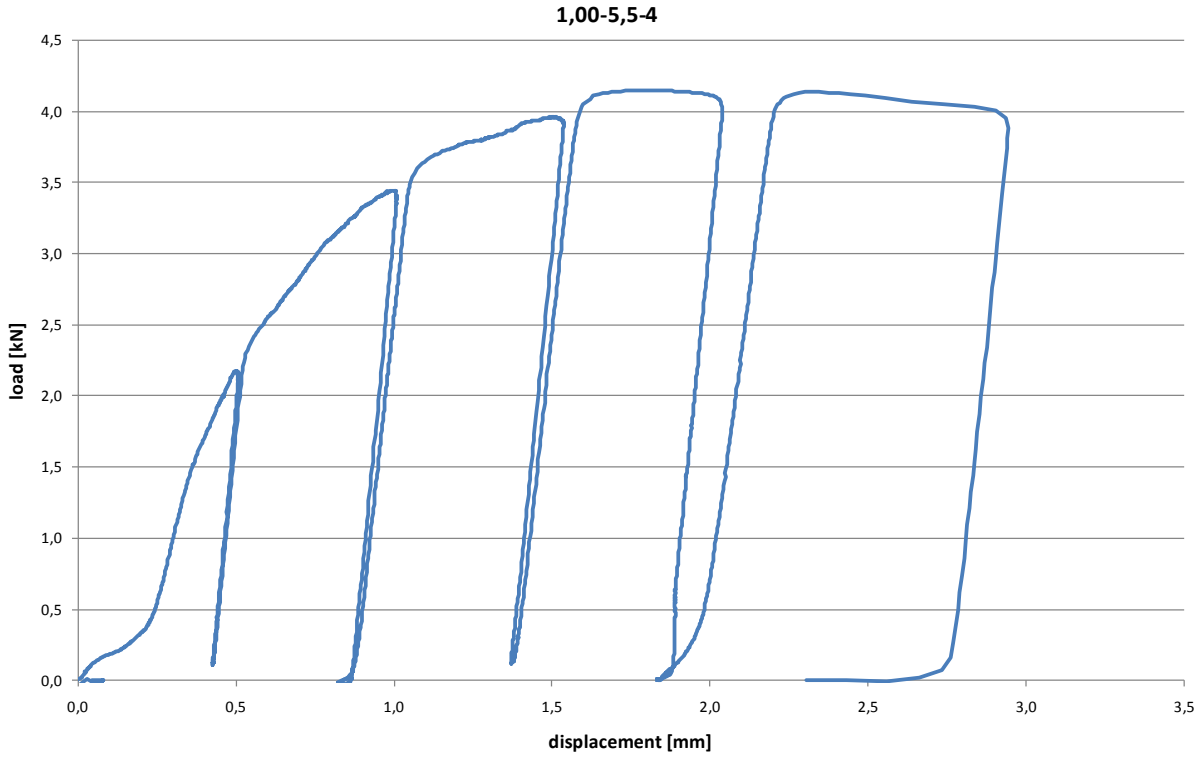
thickness of steel sheet: 1,00 mm

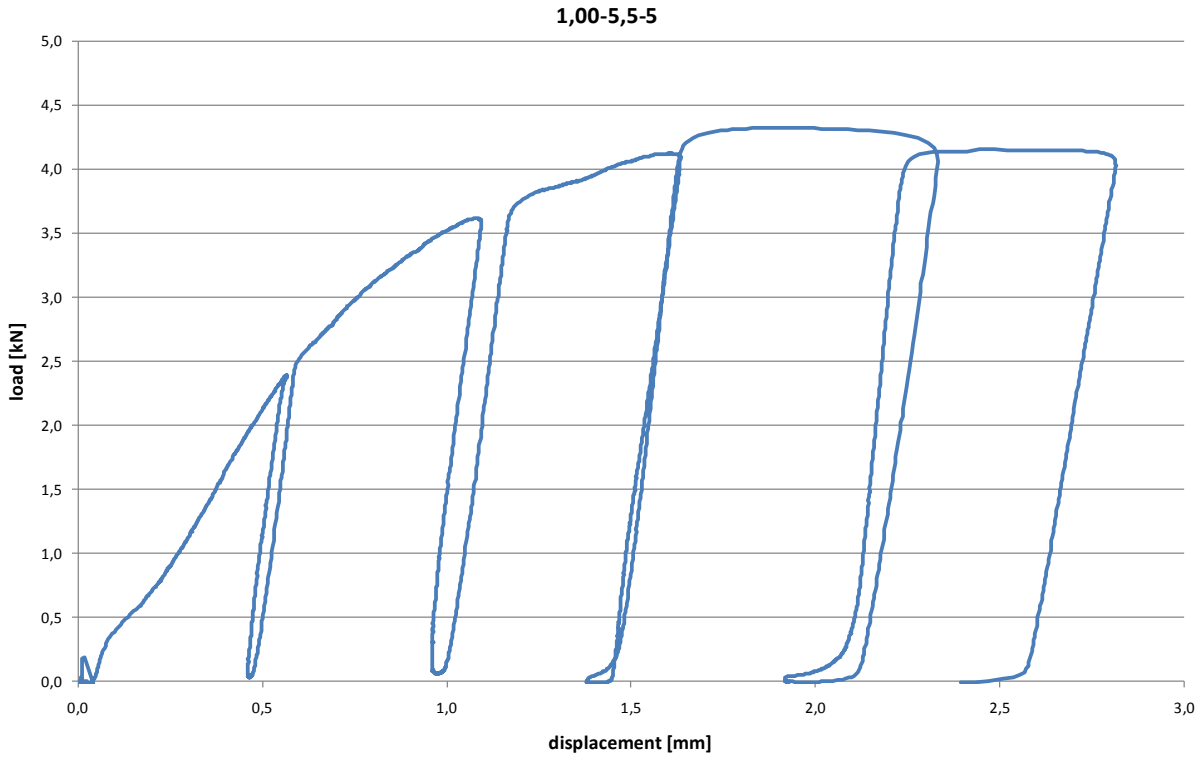
nominal diameter of fastener: 5,5 mm






1,00-5,5-3
load [kN]
displacement [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
4,5
5,0

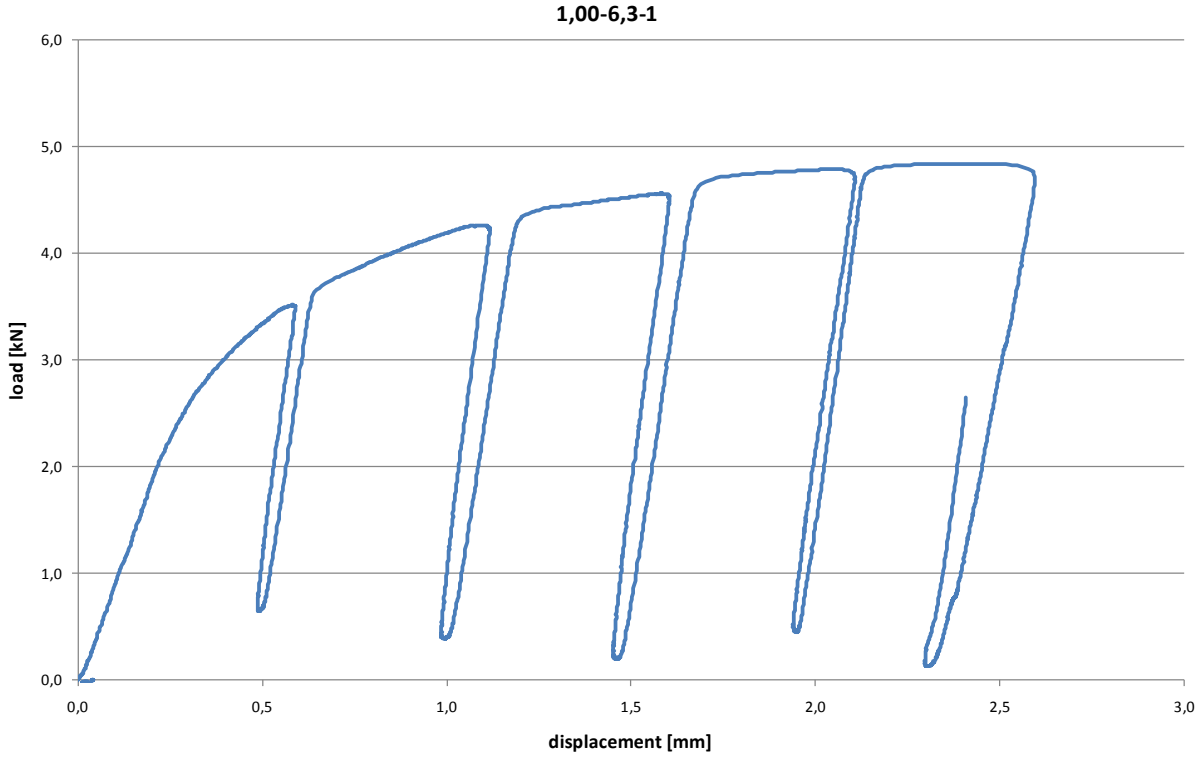

1,00-5,5-4
load [kN]
displacement [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
4,5

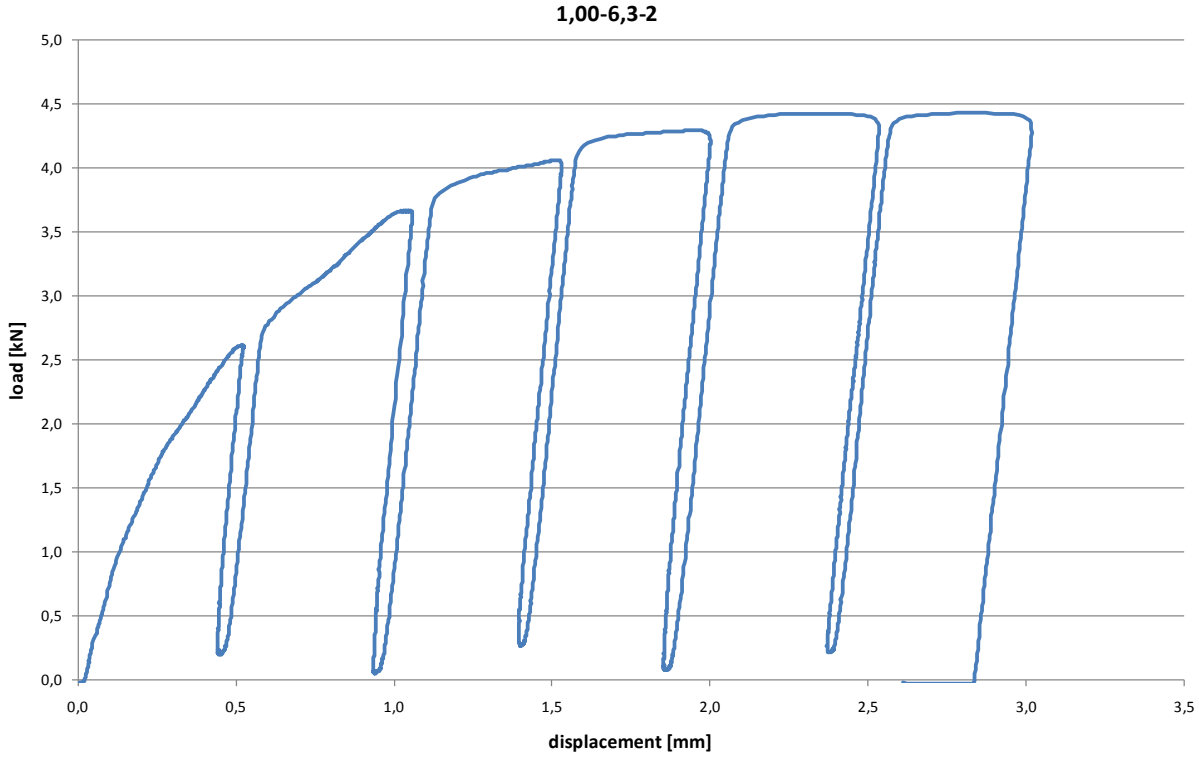

1,00-5,5-5
load [kN]
displacement [mm]
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0

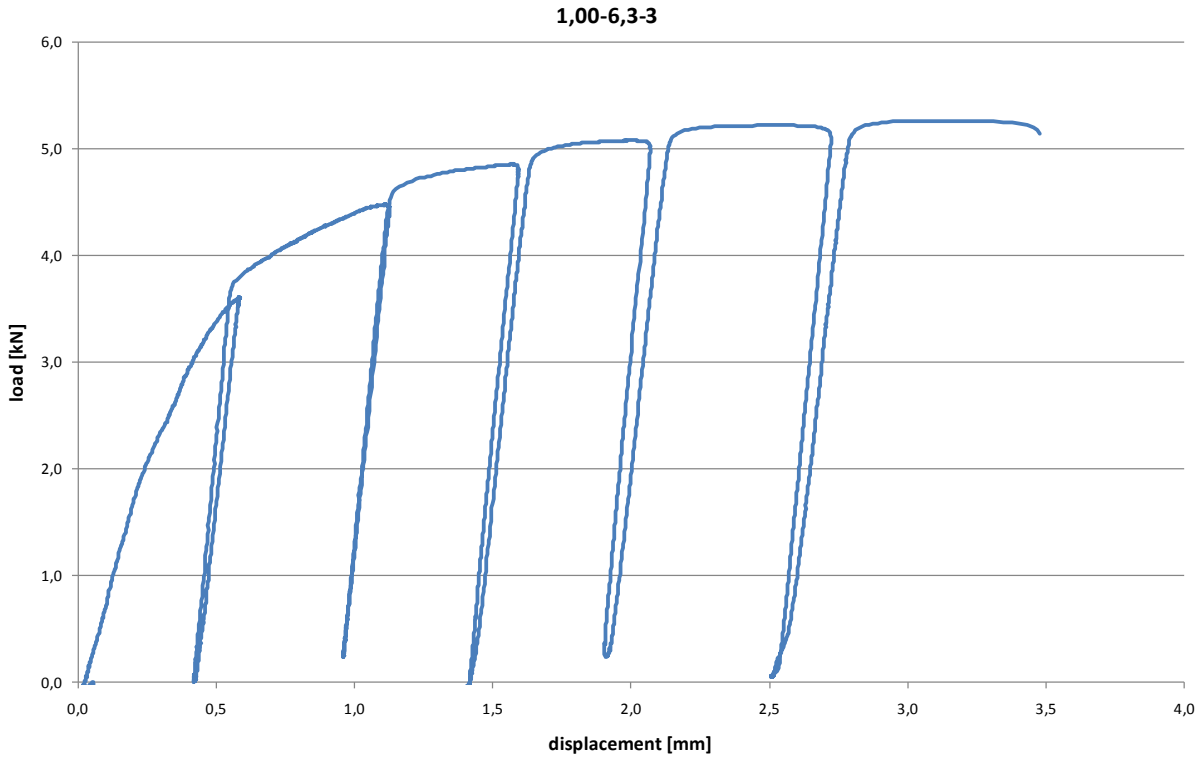
Hole elongation tests

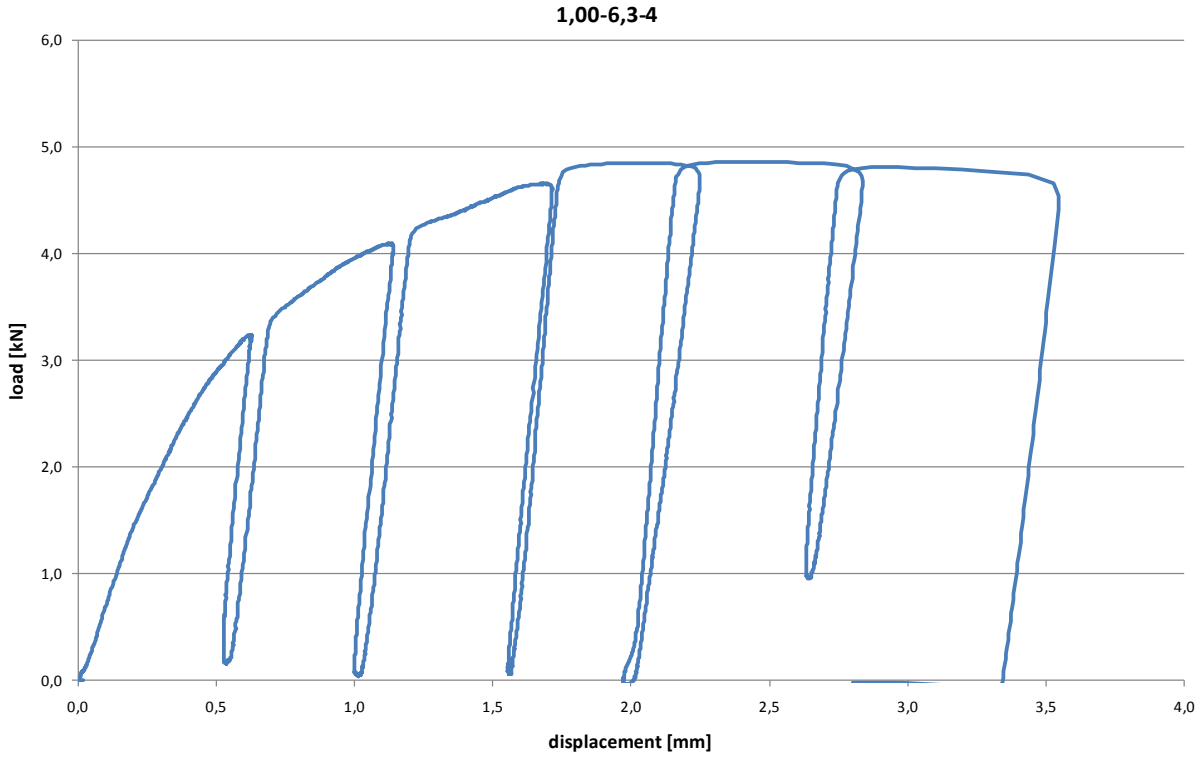
thickness of steel sheet: 1,00 mm

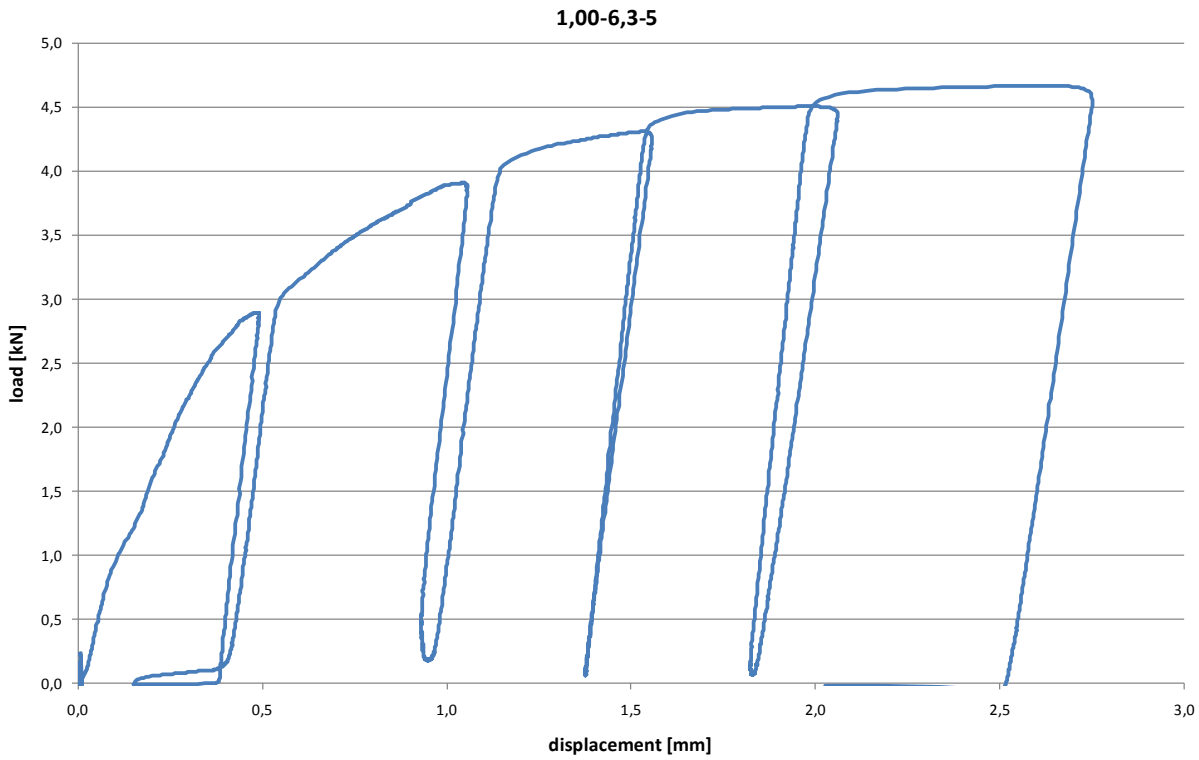
nominal diameter of fastener: 6,3 mm






1,00-6,3-3
load [kN]
displacement [mm]
0,0
1,0
2,0
3,0
4,0
5,0
6,0
0,5
1,5
2,5
3,5

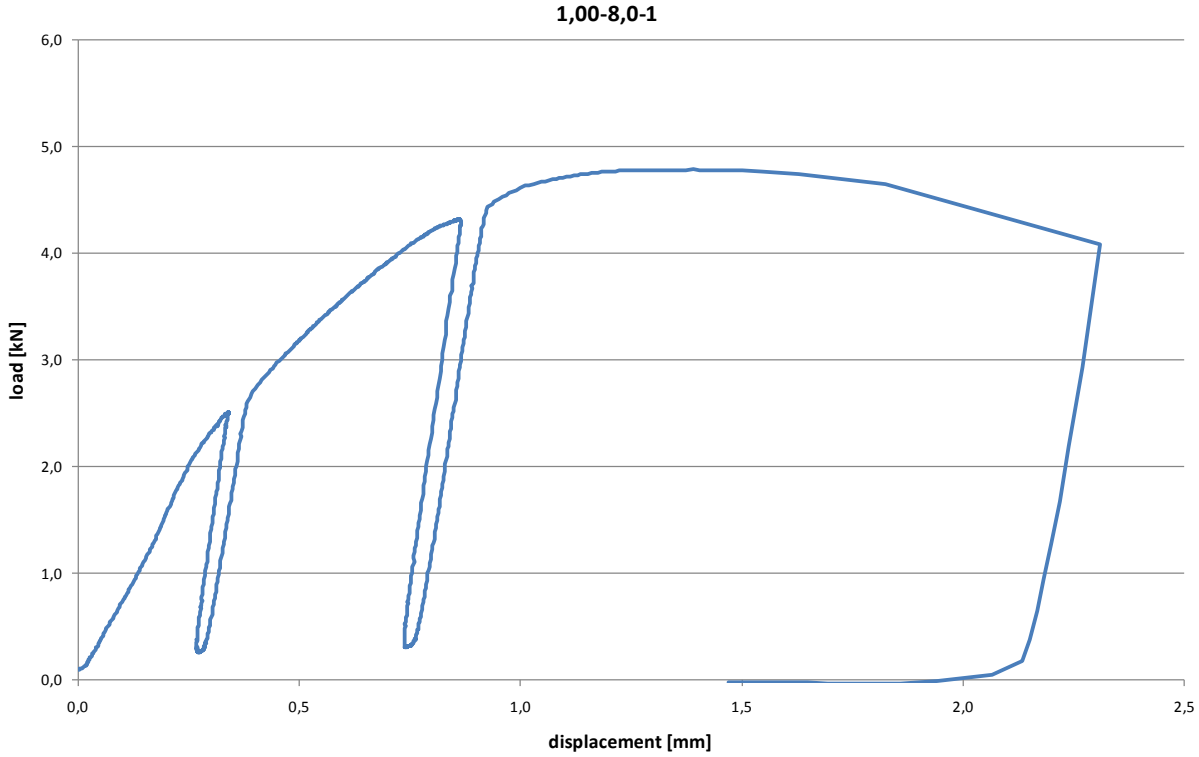

1,00-6,3-4
load [kN]
displacement [mm]
0,0
1,0
2,0
3,0
4,0
5,0
6,0
0,5
1,5
2,5
3,5

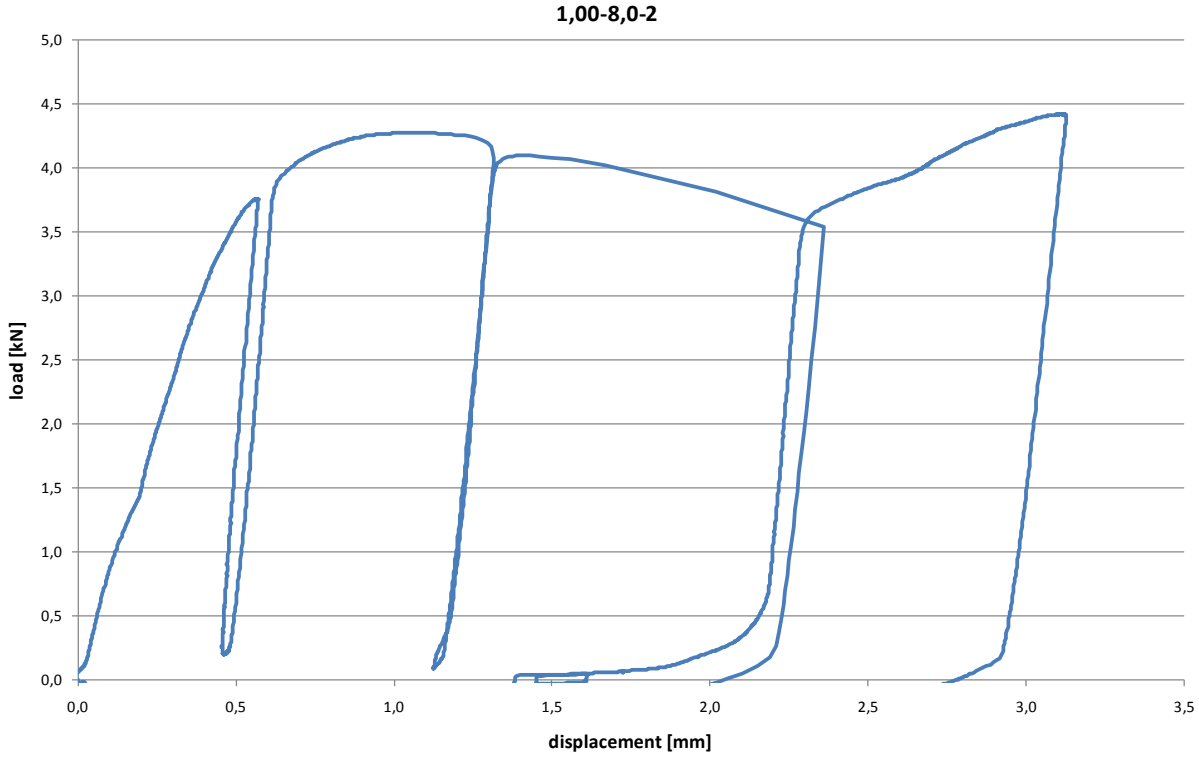

1,00-6,3-5
load [kN]
displacement [mm]
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0

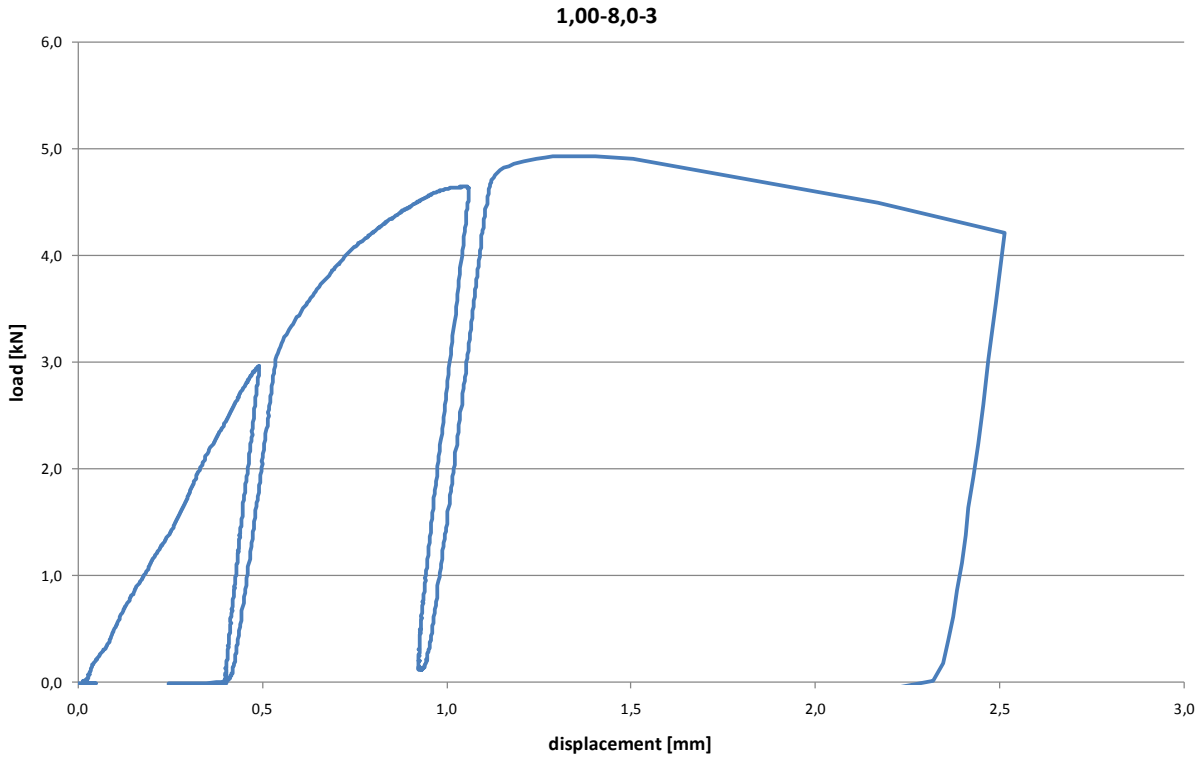
Hole elongation tests

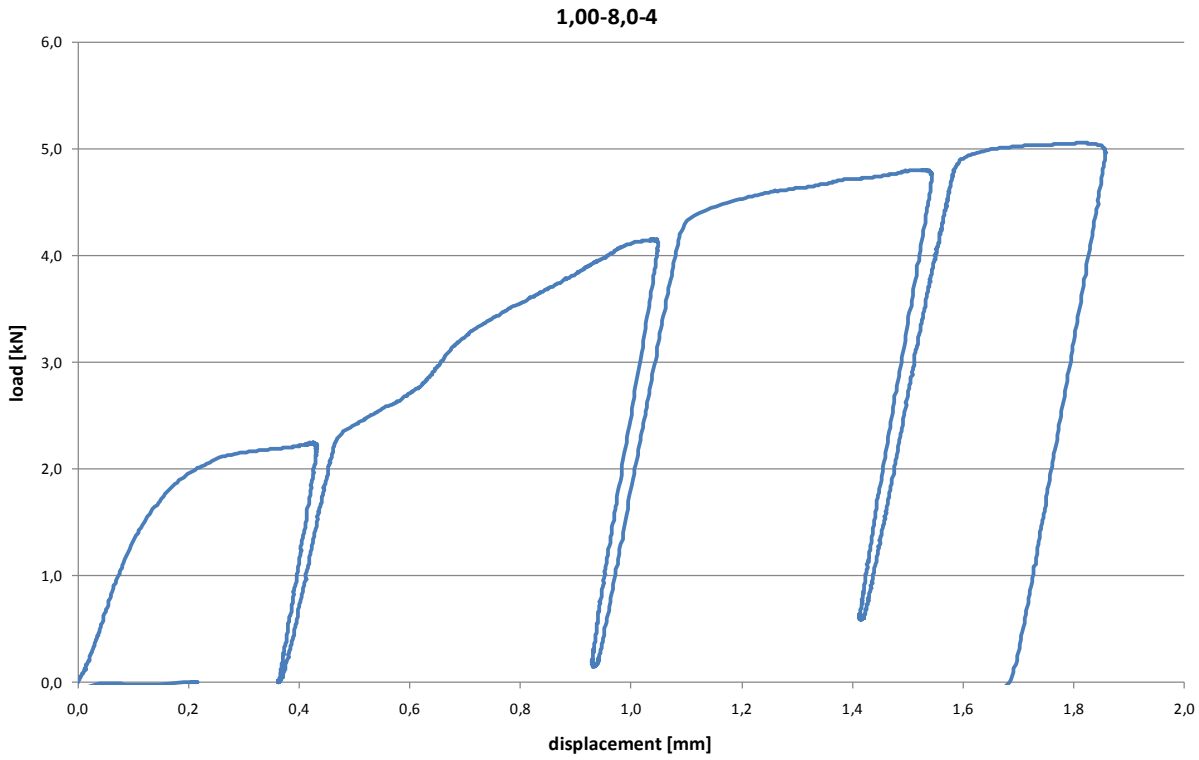
thickness of steel sheet: 1,00 mm

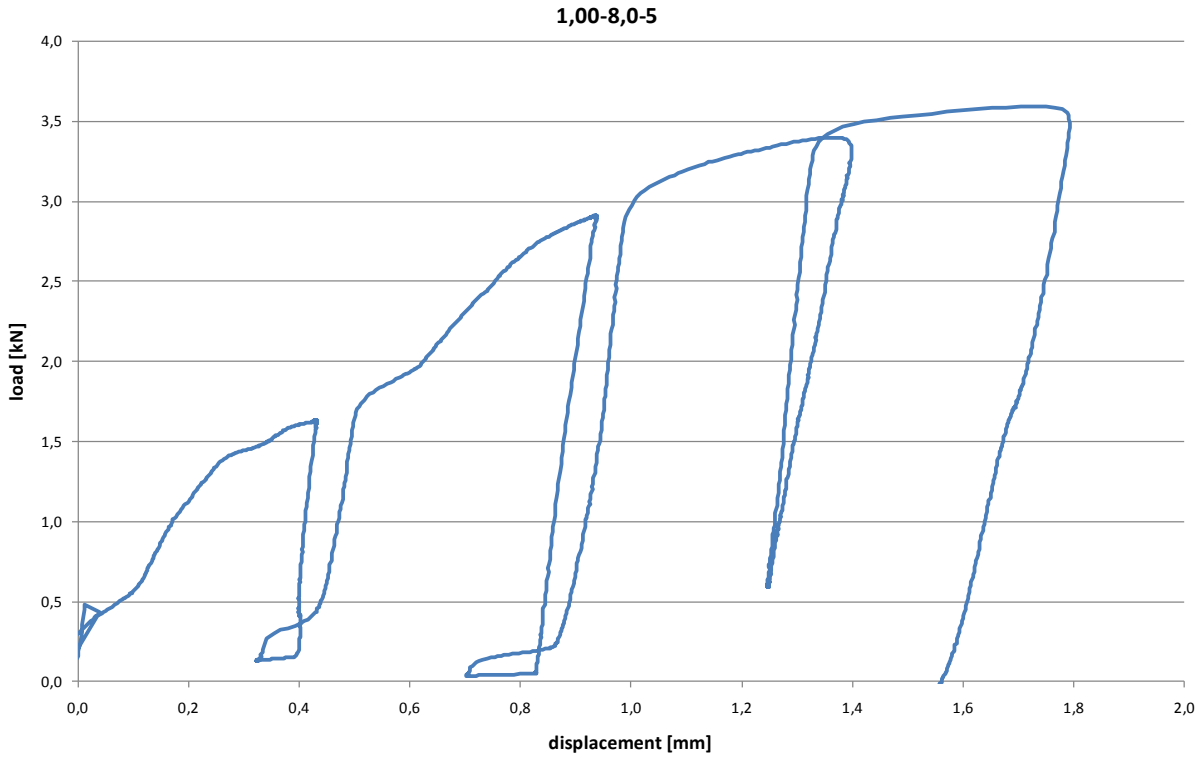
nominal diameter of fastener: 8,0 mm






1,00-8,0-3
load [kN]
displacement [mm]
6,0
5,0
4,0
3,0
2,0
1,0
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0


1,00-8,0-4
load [kN]
displacement [mm]
6,0
5,0
4,0
3,0
2,0
1,0
0,0
0,0
0,2
0,4
0,6
0,8
1,0
1,2
1,4
1,6
1,8
2,0

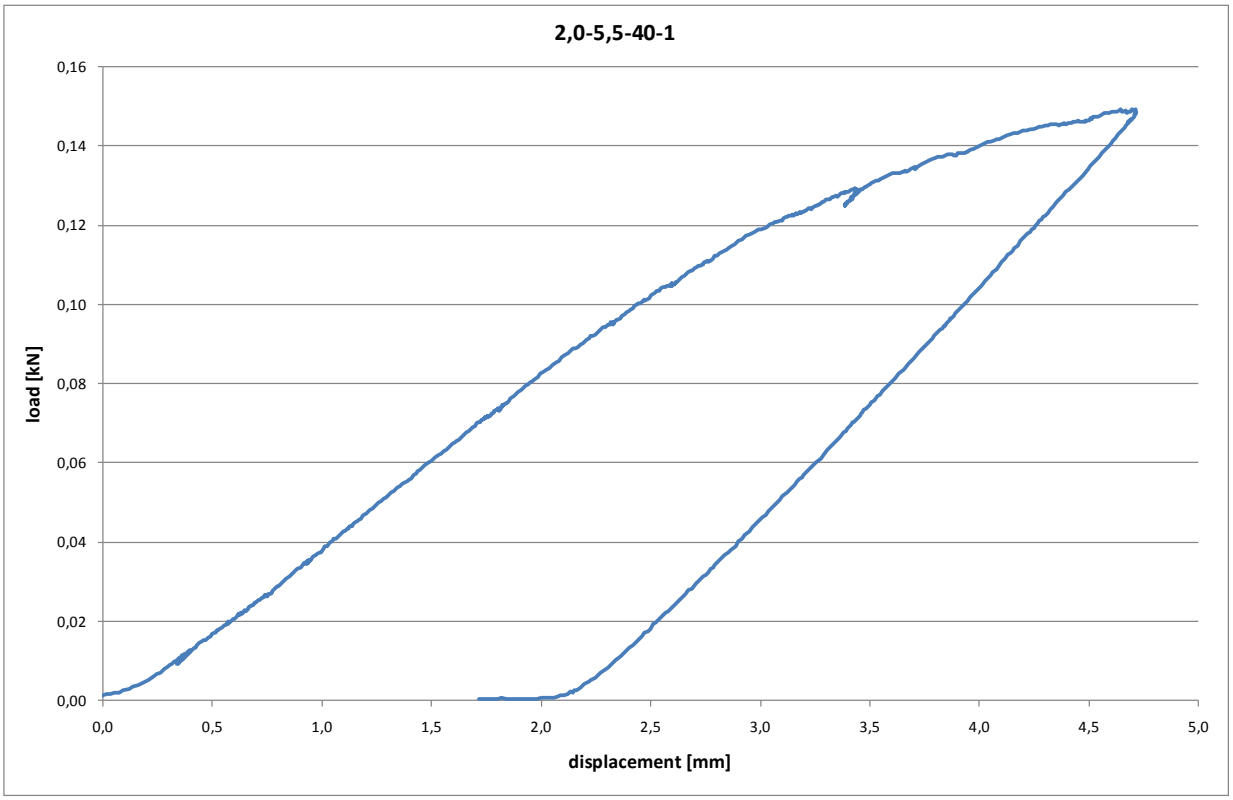

1,00-8,0-5
load [kN]
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0,0
0,2
0,4
0,6
0,8
1,0
1,2
1,4
1,6
1,8
2,0
displacement [mm]

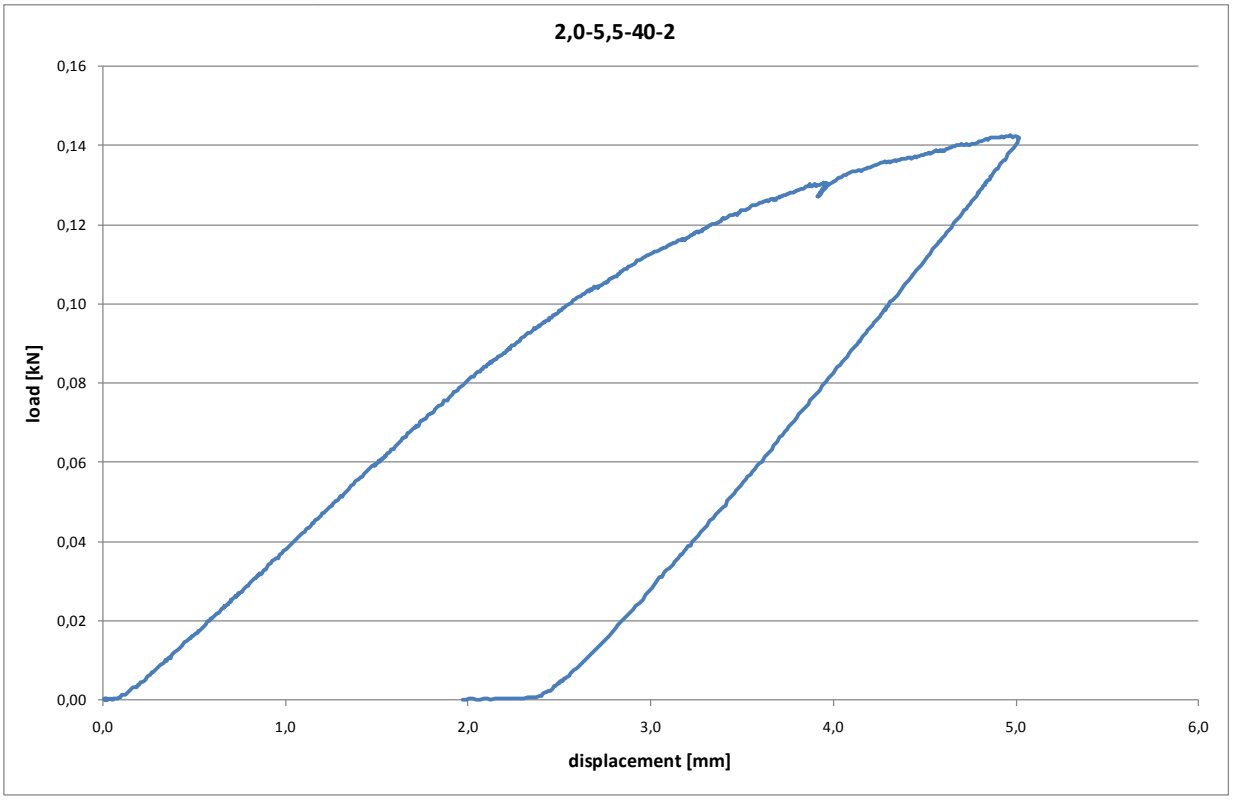
Bending tests

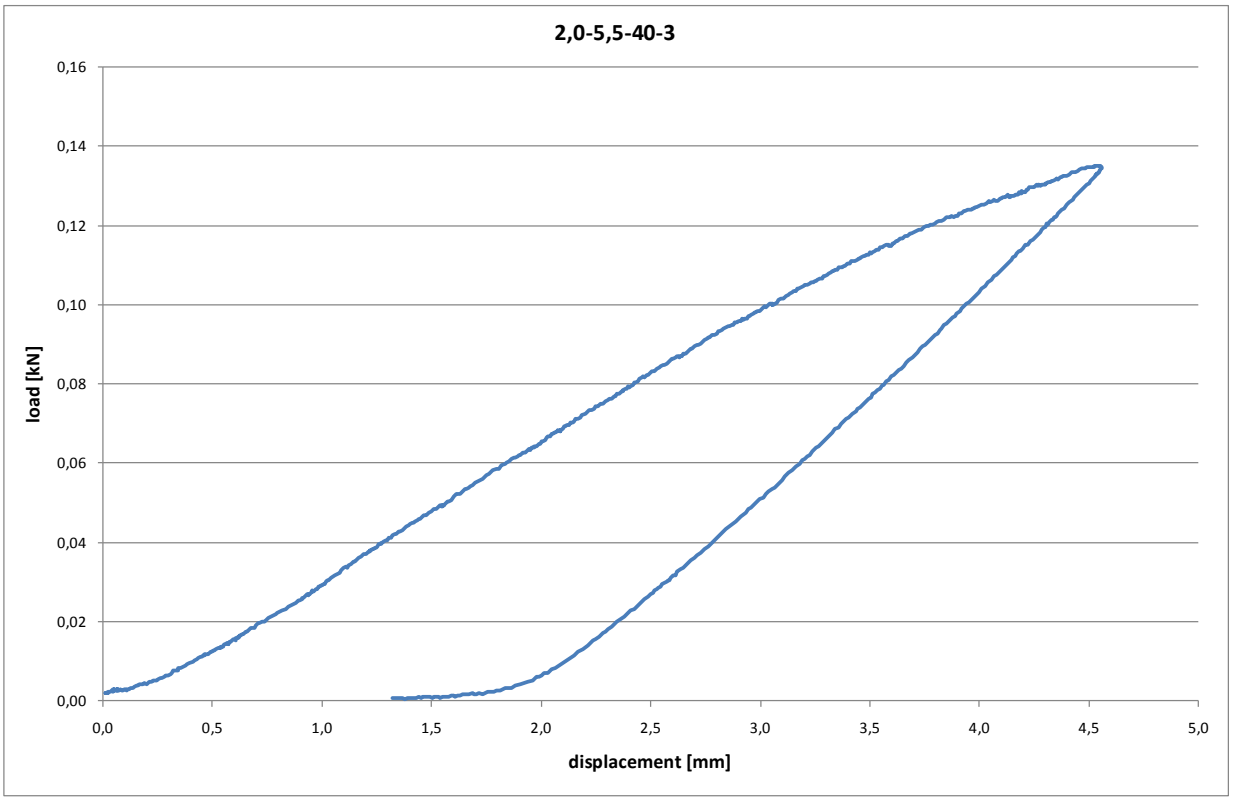
Thickness of substructure: 2,0 mm

Nominal diameter of fastener: 5,5 mm

Lever arm: 40 mm




2,0-5,5-40-2
load [kN]
0,16
0,14
0,12
0,10
0,08
0,06
0,04
0,02
0,00
0,0
1,0
2,0
3,0
4,0
5,0
6,0
displacement [mm]

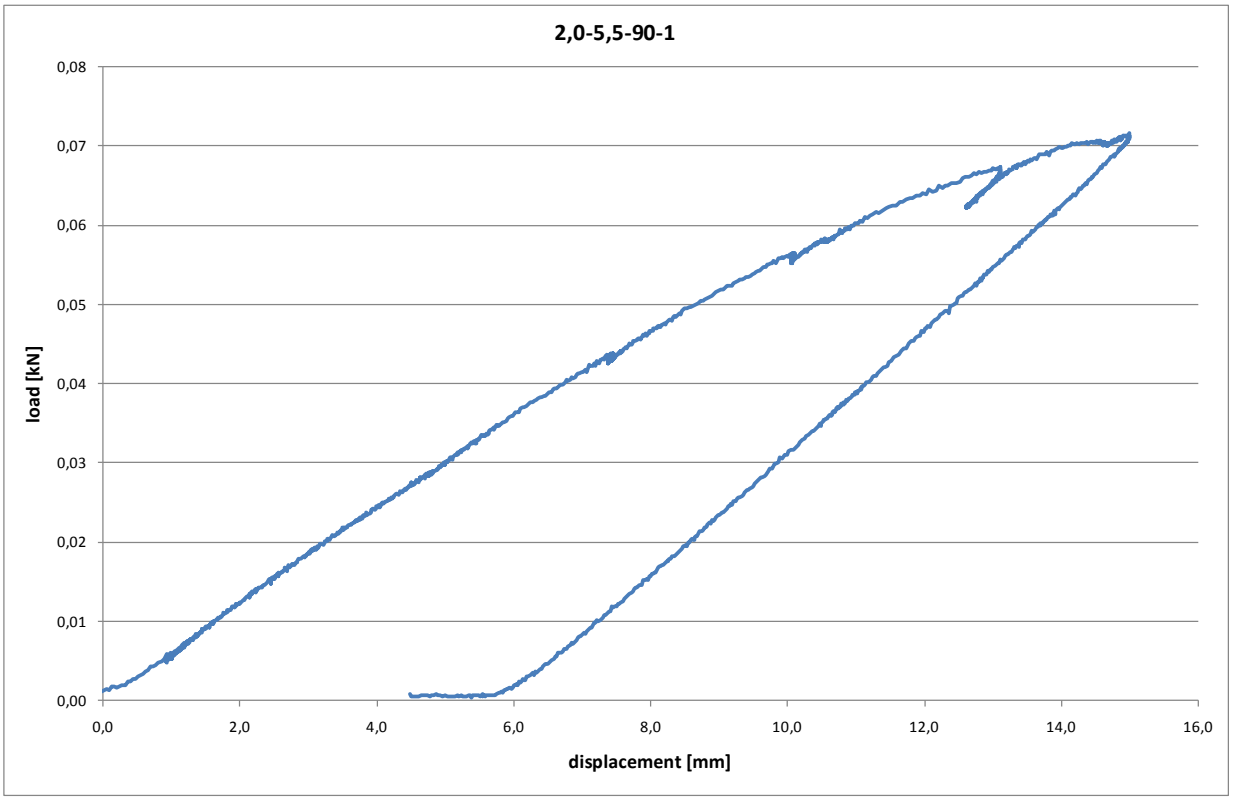

2,0-5,5-40-3
load [kN]
0,16
0,14
0,12
0,10
0,08
0,06
0,04
0,02
0,00
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
4,5
5,0
displacement [mm]

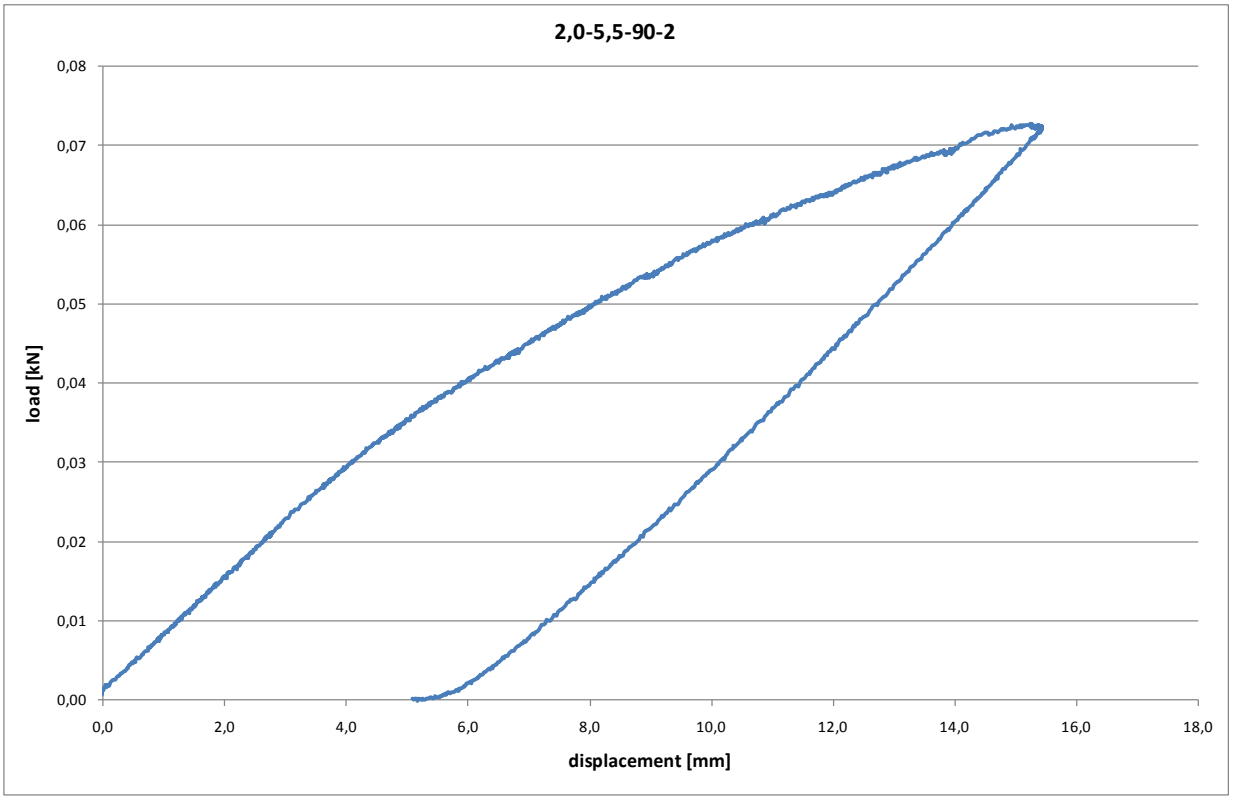
Bending tests

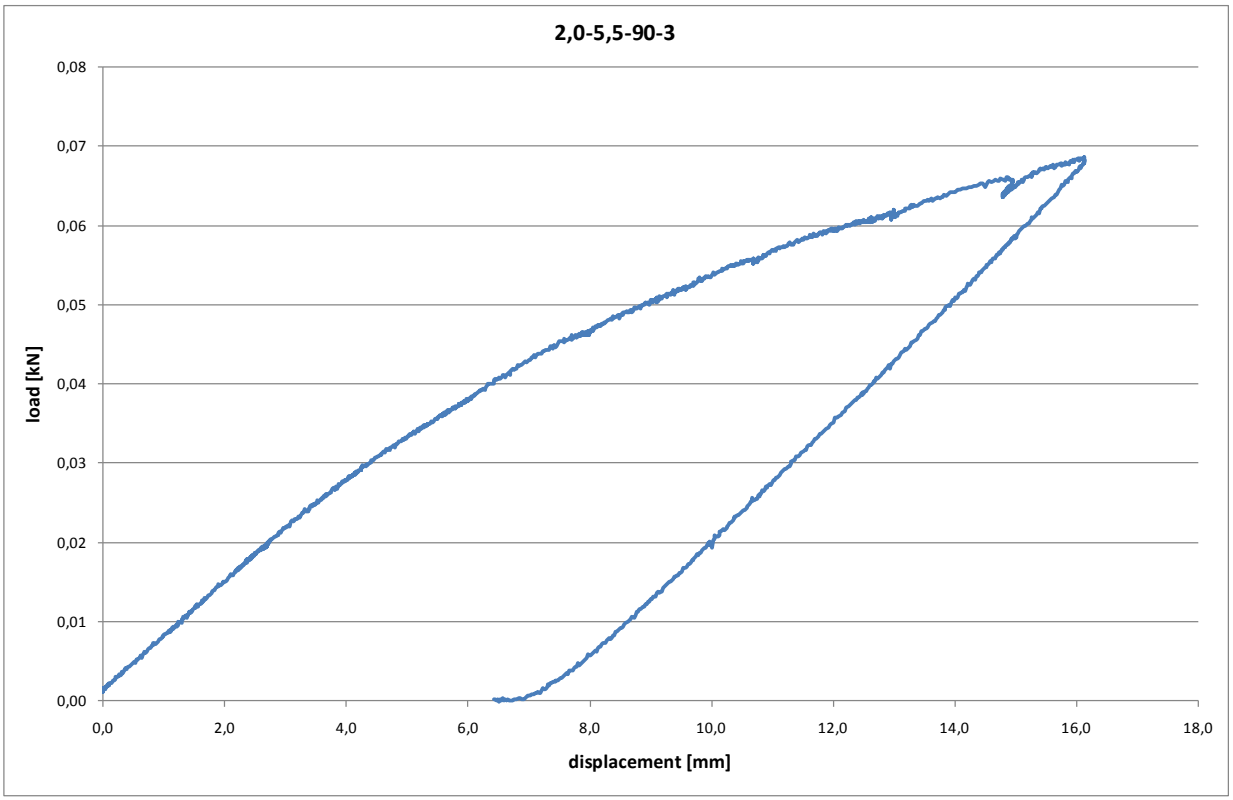
Thickness of substructure: 2,0 mm

Nominal diameter of fastener: 5,5 mm

Lever arm: 90 mm




2,0-5,5-90-2
load [kN]
0,08
0,07
0,06
0,05
0,04
0,03
0,02
0,01
0,00
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
18,0
displacement [mm]

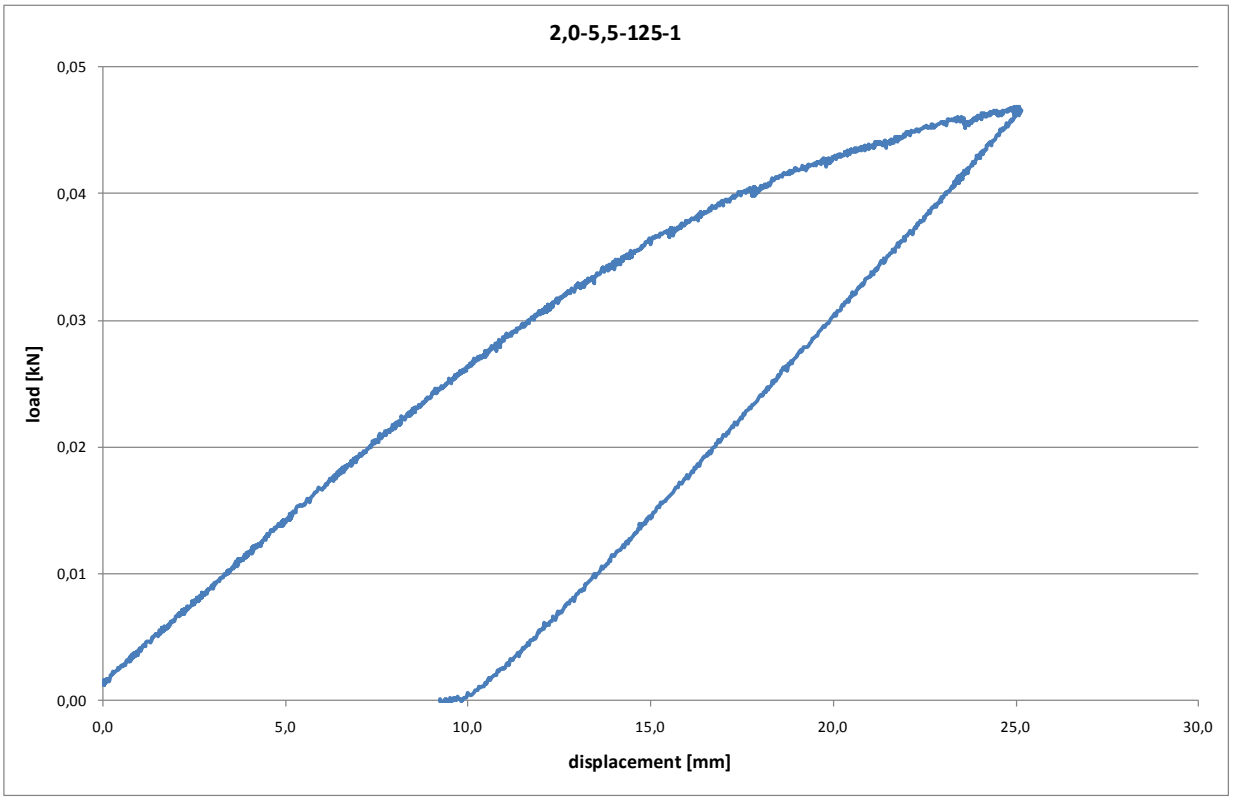

2,0-5,5-90-3
load [kN]
0,08
0,07
0,06
0,05
0,04
0,03
0,02
0,01
0,00
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
18,0
displacement [mm]

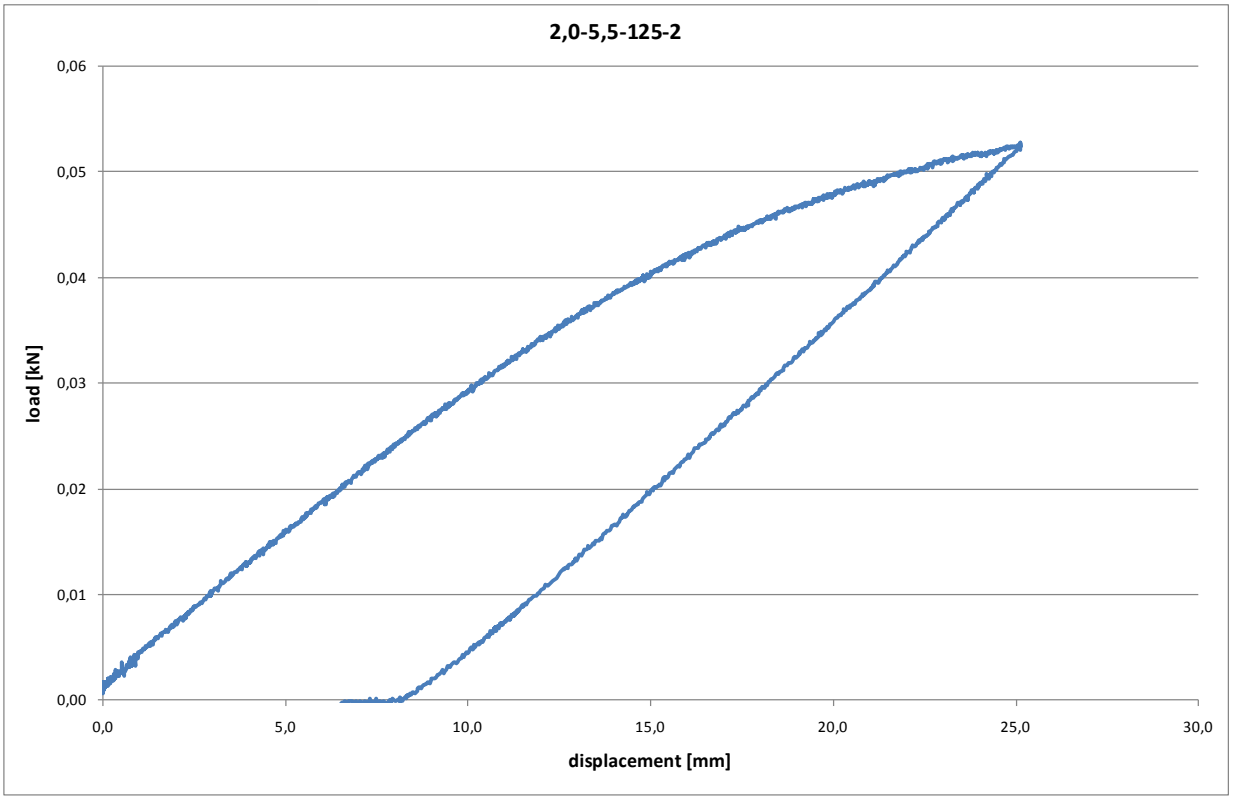
Bending tests

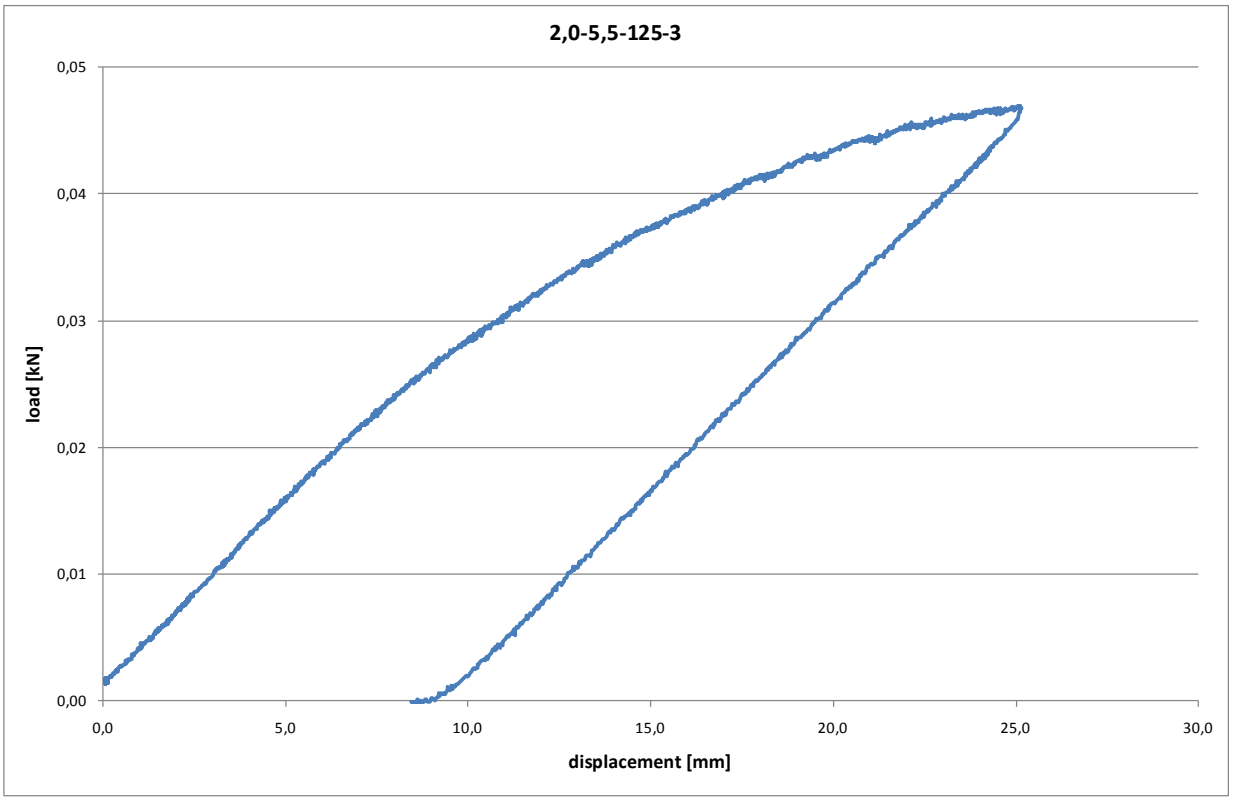
Thickness of substructure: 2,0 mm

Nominal diameter of fastener: 5,5 mm

Lever arm: 125 mm




2,0-5,5-125-2
load [kN]
0,06
0,05
0,04
0,03
0,02
0,01
0,00
0,0
5,0
10,0
15,0
20,0
25,0
30,0
displacement [mm]

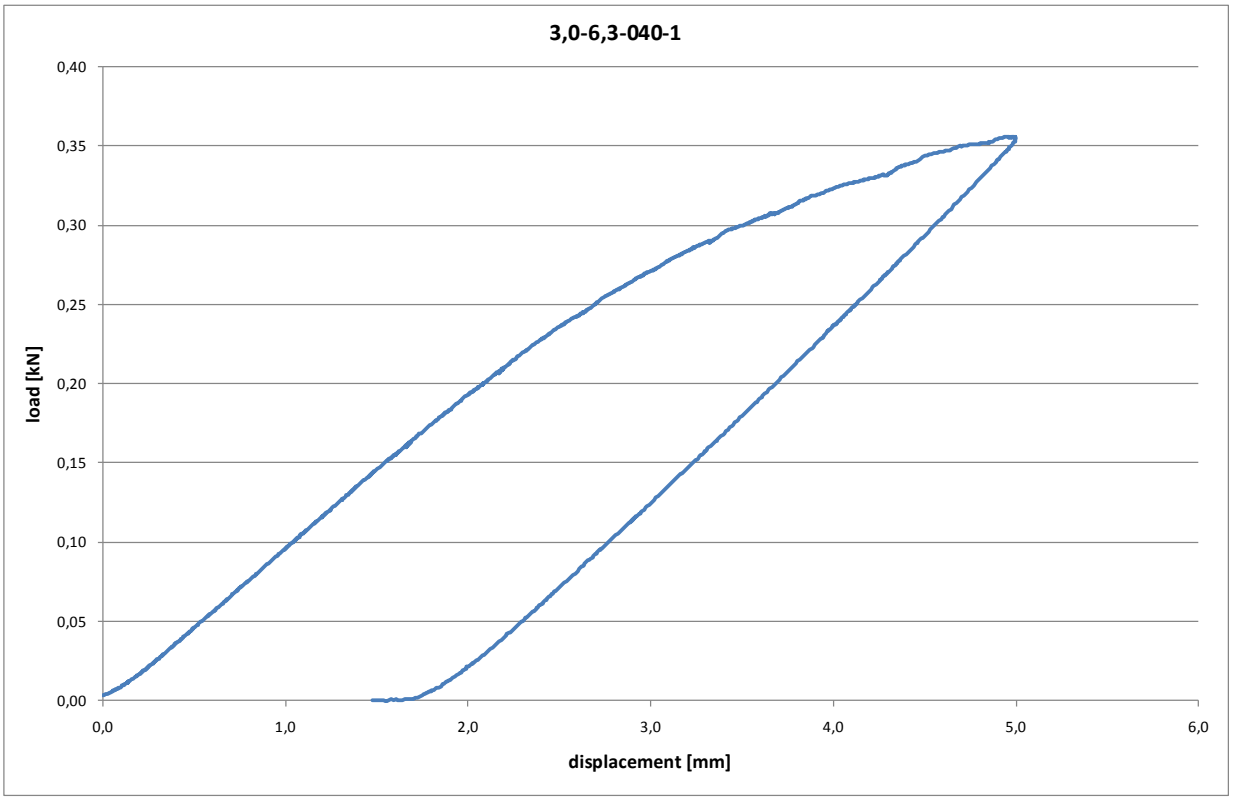

2,0-5,5-125-3
load [kN]
0,05
0,04
0,03
0,02
0,01
0,00
0,0
5,0
10,0
15,0
20,0
25,0
30,0
displacement [mm]

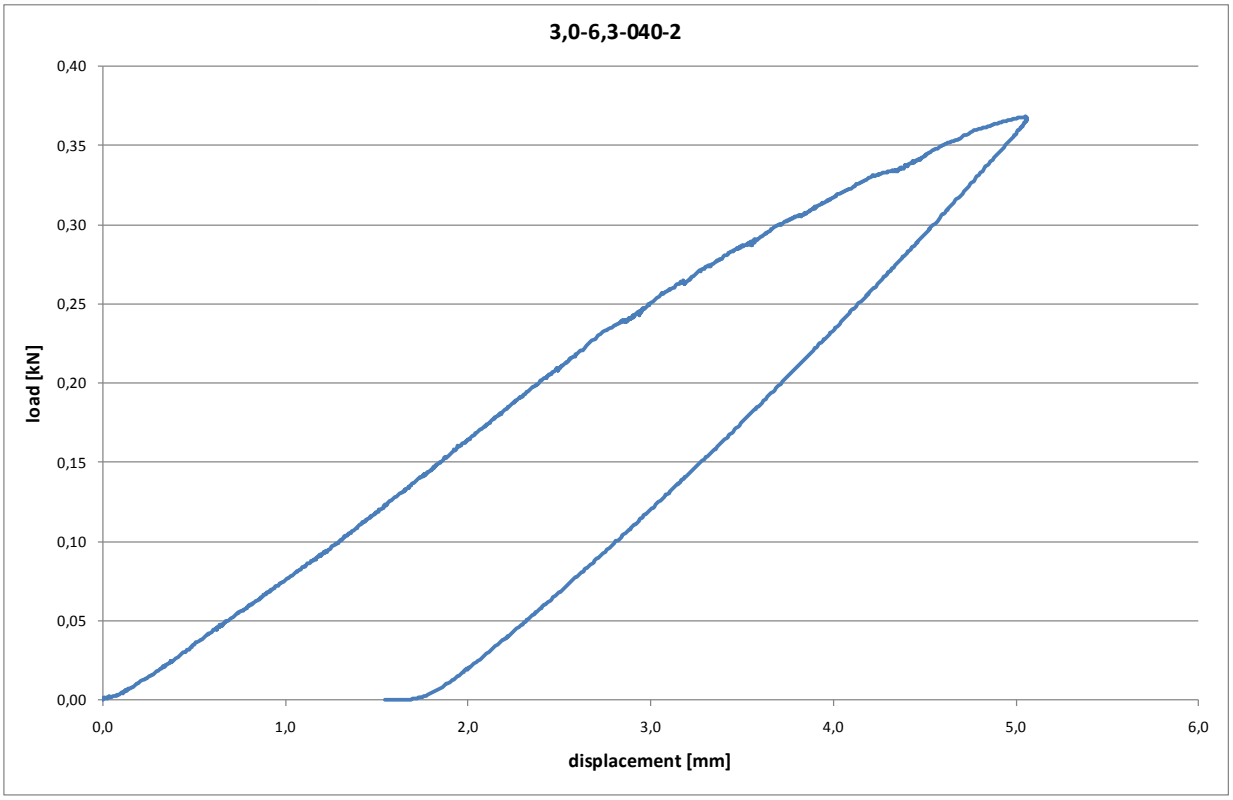
Bending tests

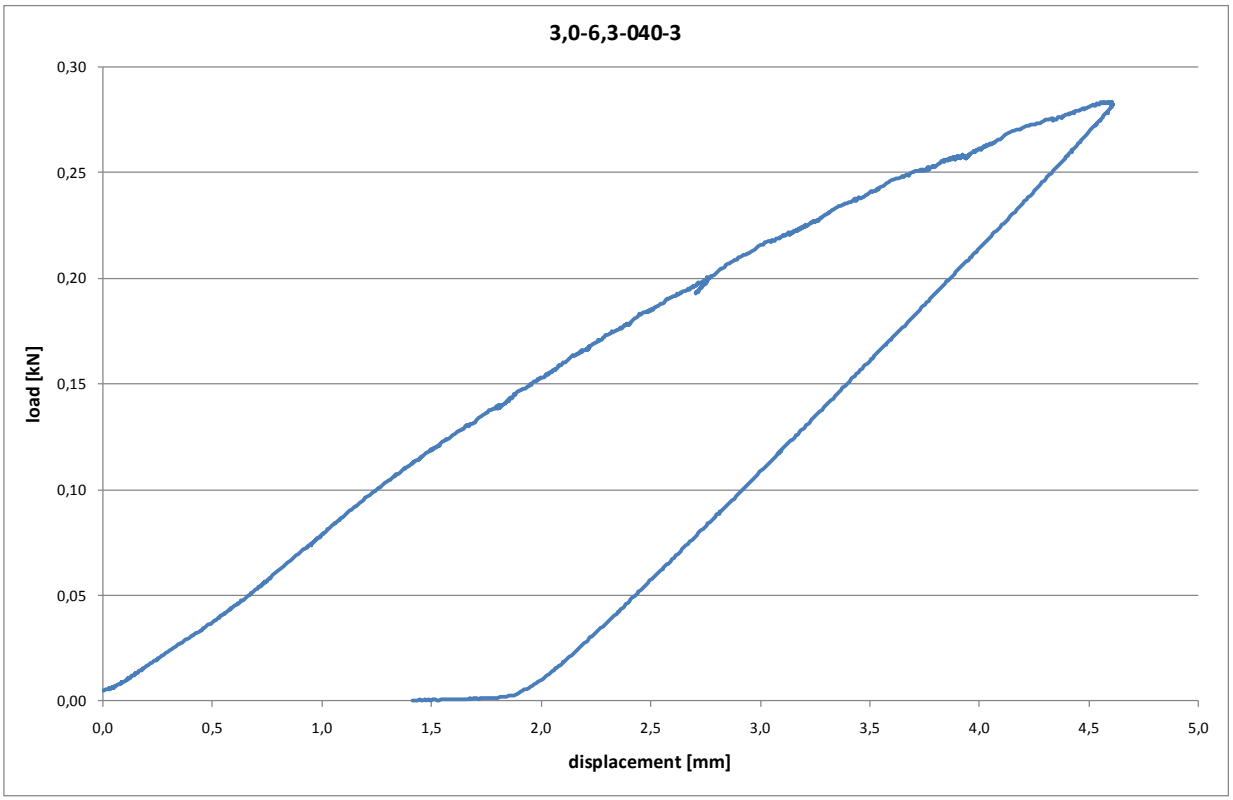
Thickness of substructure: 3,0 mm

Nominal diameter of fastener: 6,3 mm

Lever arm: 40 mm




3,0-6,3-040-2
load [kN]
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
0,0
1,0
2,0
3,0
4,0
5,0
6,0
displacement [mm]

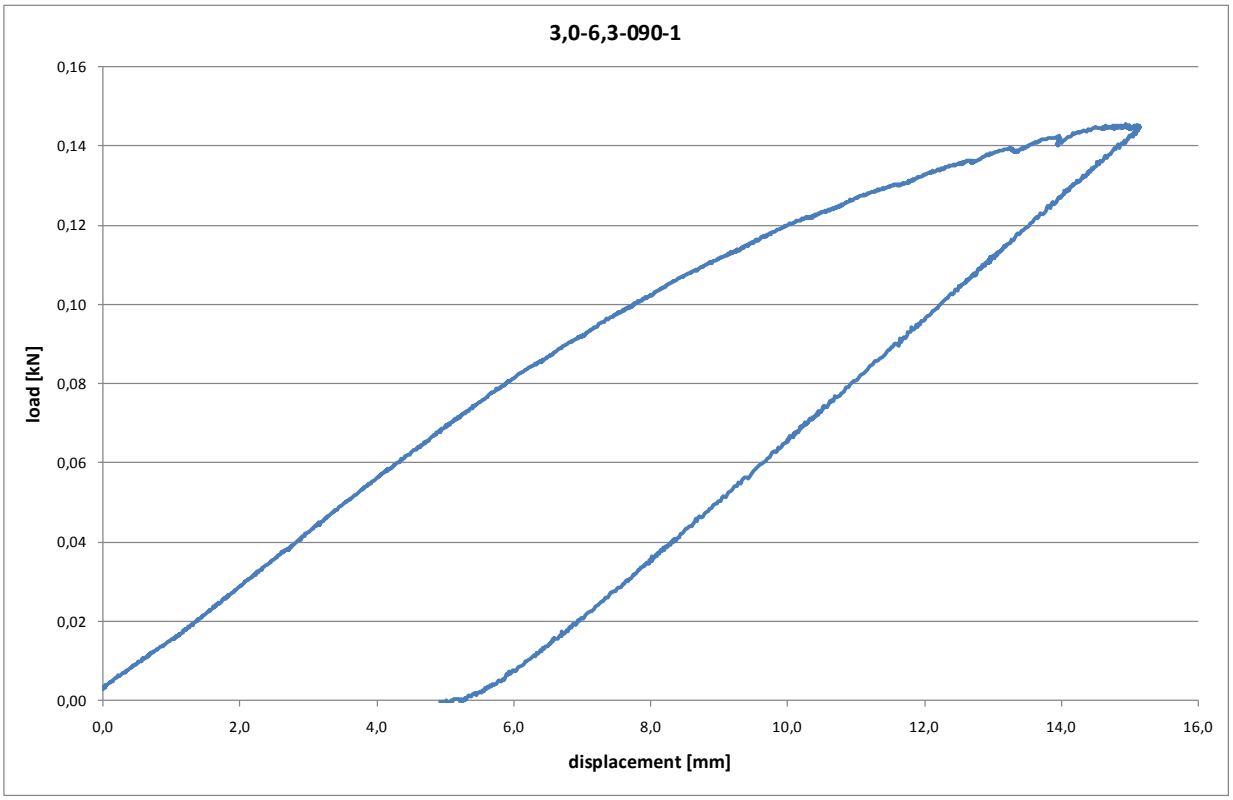

3,0-6,3-040-3
load [kN]
0,30
0,25
0,20
0,15
0,10
0,05
0,00
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
4,5
5,0
displacement [mm]

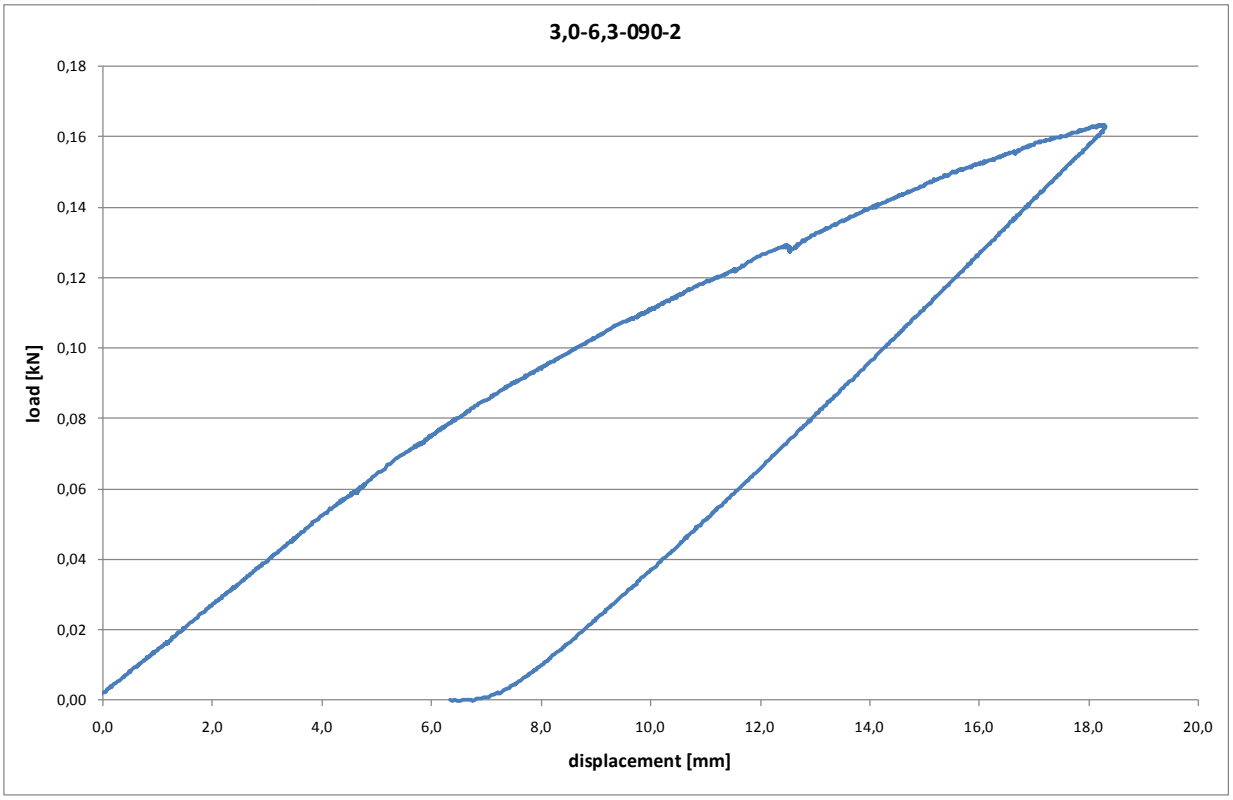
Bending tests

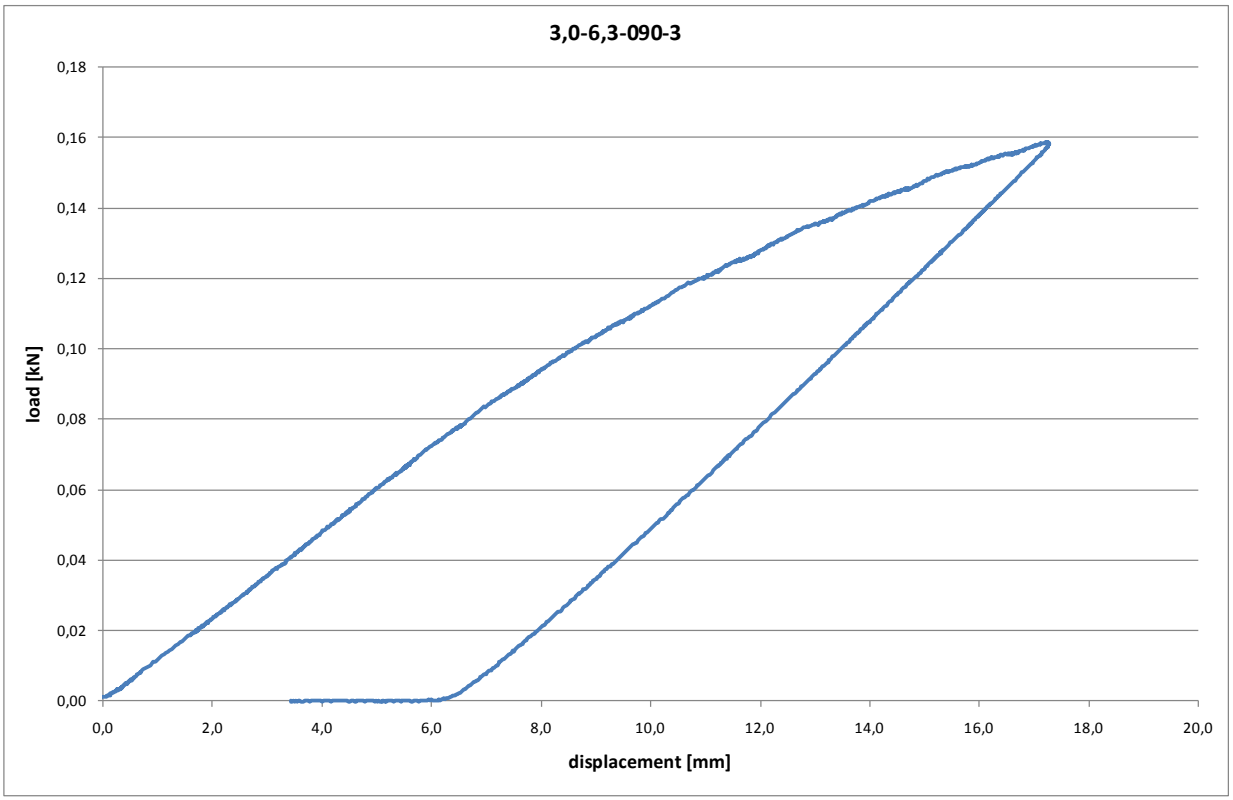
Thickness of substructure: 3,0 mm

Nominal diameter of fastener: 6,3 mm

Lever arm: 90 mm




3,0-6,3-090-2
load [kN]
0,18
0,16
0,14
0,12
0,10
0,08
0,06
0,04
0,02
0,00
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
18,0
20,0
displacement [mm]

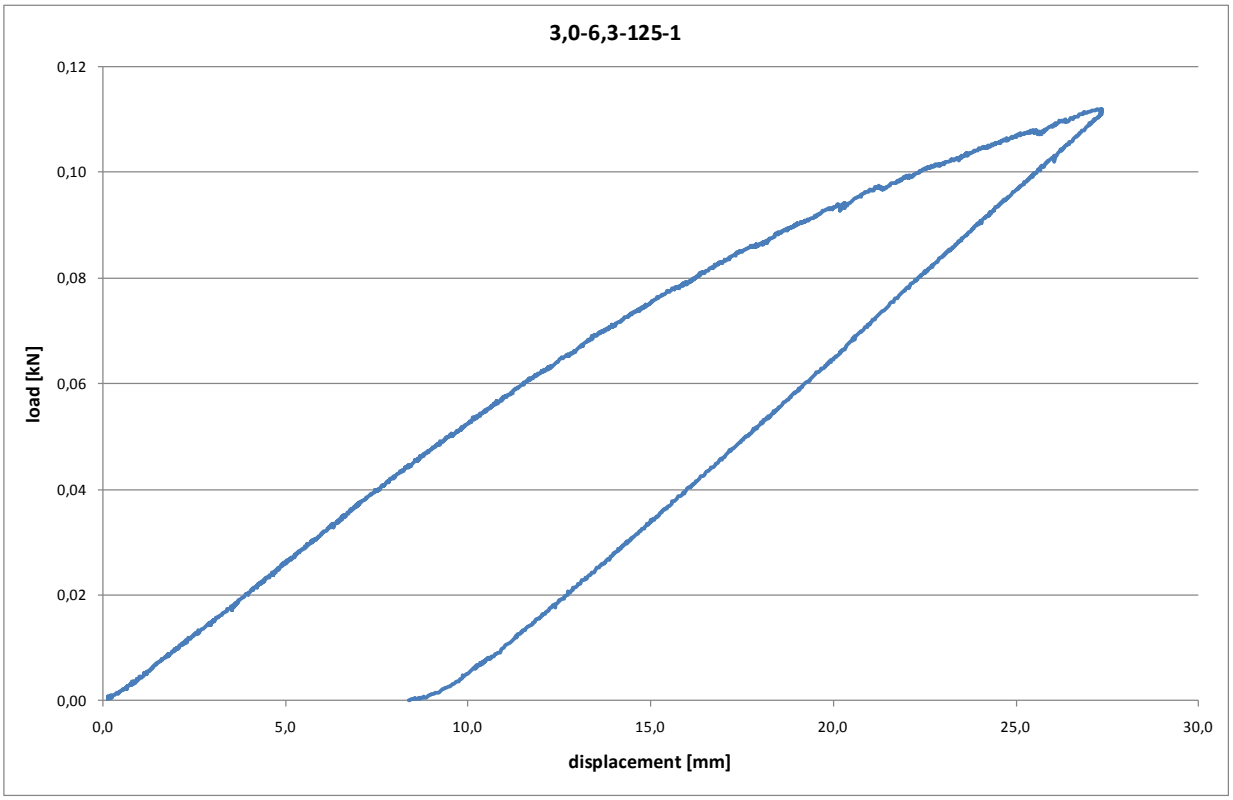

3,0-6,3-090-3
load [kN]
0,18
0,16
0,14
0,12
0,10
0,08
0,06
0,04
0,02
0,00
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
18,0
20,0
displacement [mm]

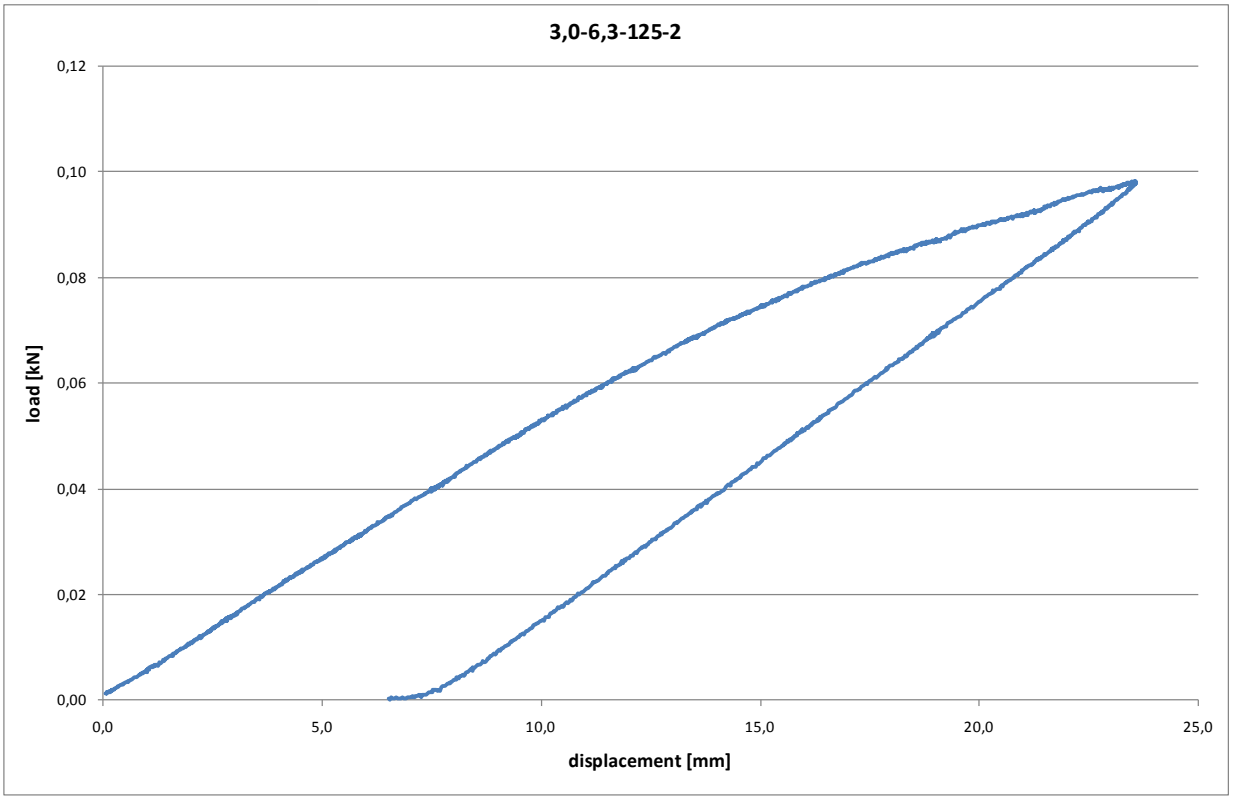
Bending tests

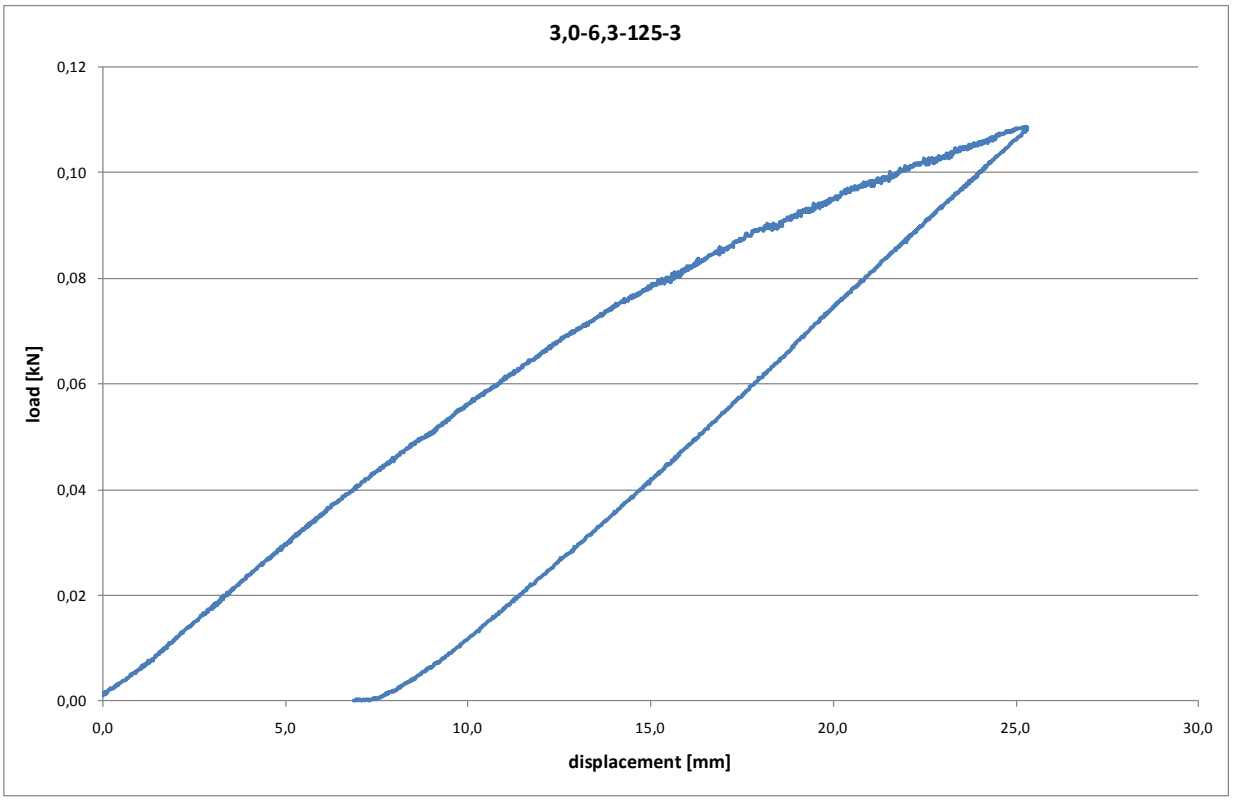
Thickness of substructure: 3,0 mm

Nominal diameter of fastener: 6,3 mm

Lever arm: 125 mm




3,0-6,3-125-2
load [kN]
0,12
0,10
0,08
0,06
0,04
0,02
0,00
0,0
5,0
10,0
15,0
20,0
25,0
displacement [mm]

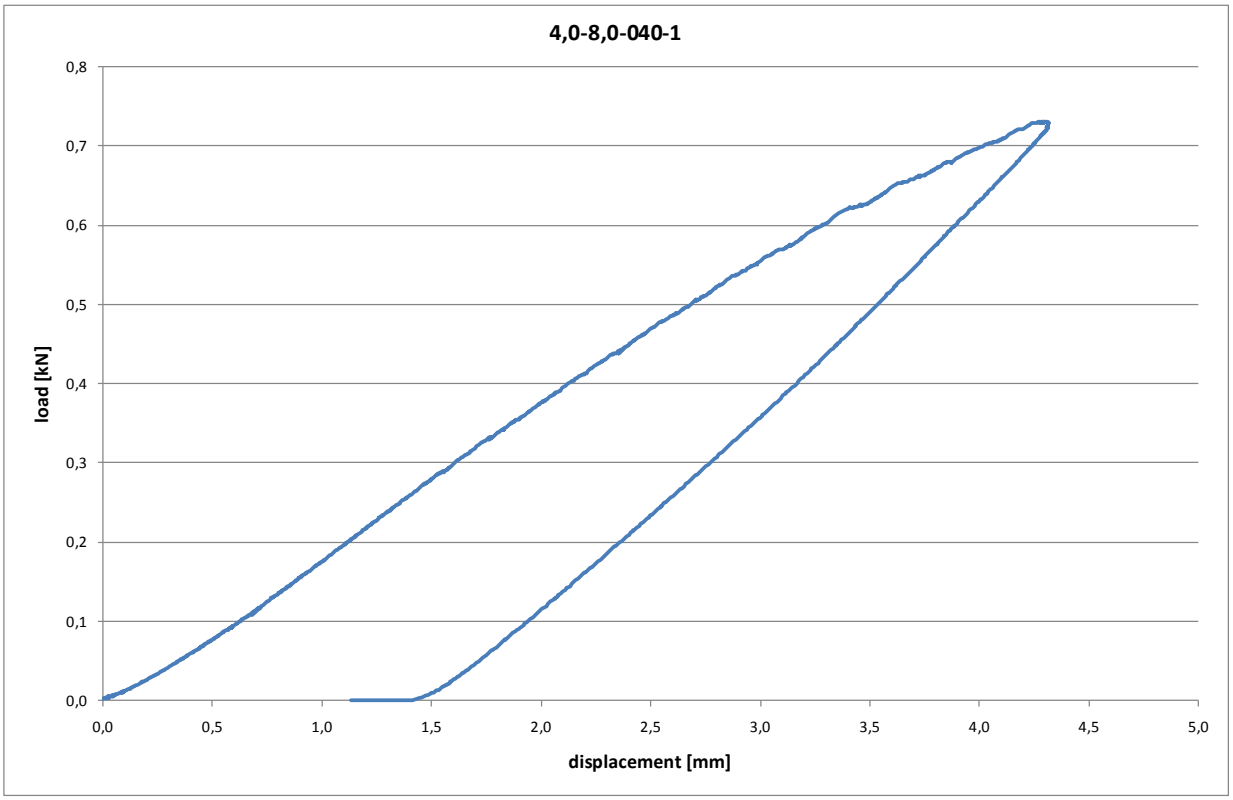

3,0-6,3-125-3
load [kN]
0,12
0,10
0,08
0,06
0,04
0,02
0,00
0,0
5,0
10,0
15,0
20,0
25,0
30,0
displacement [mm]

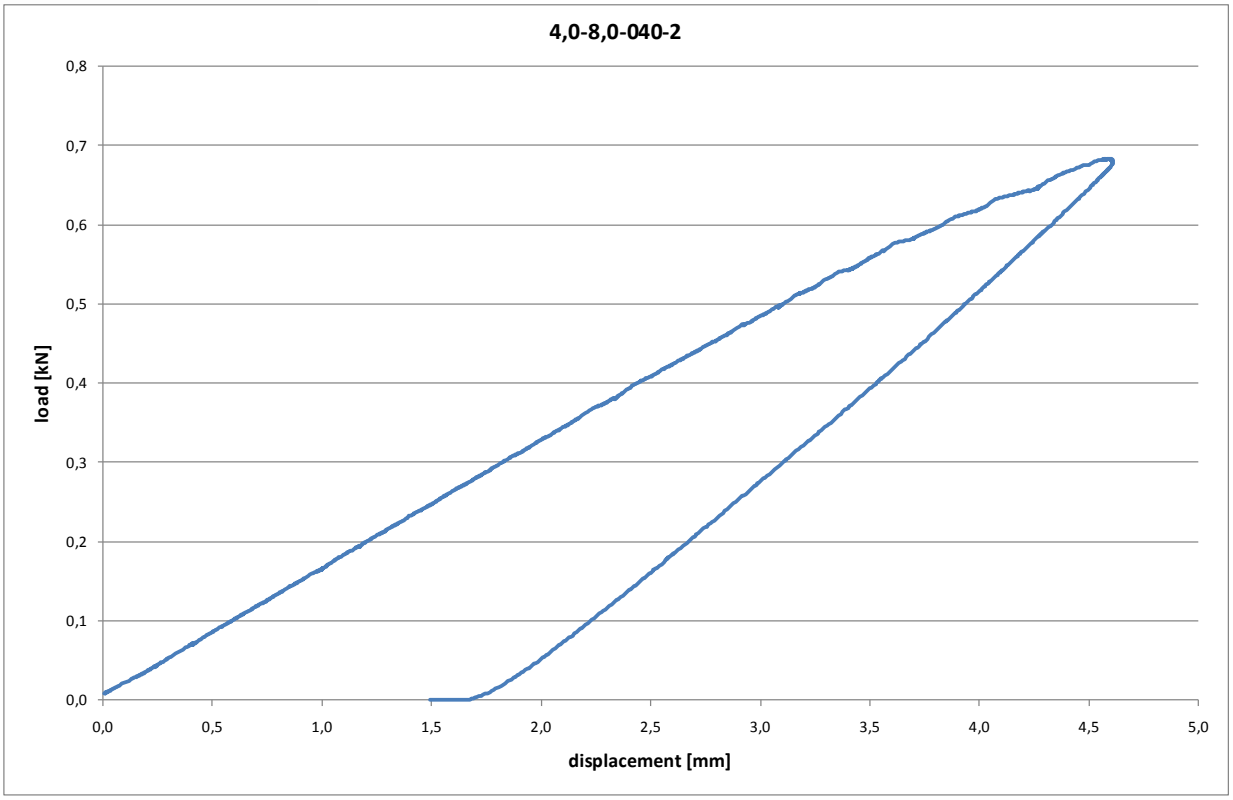
Bending tests

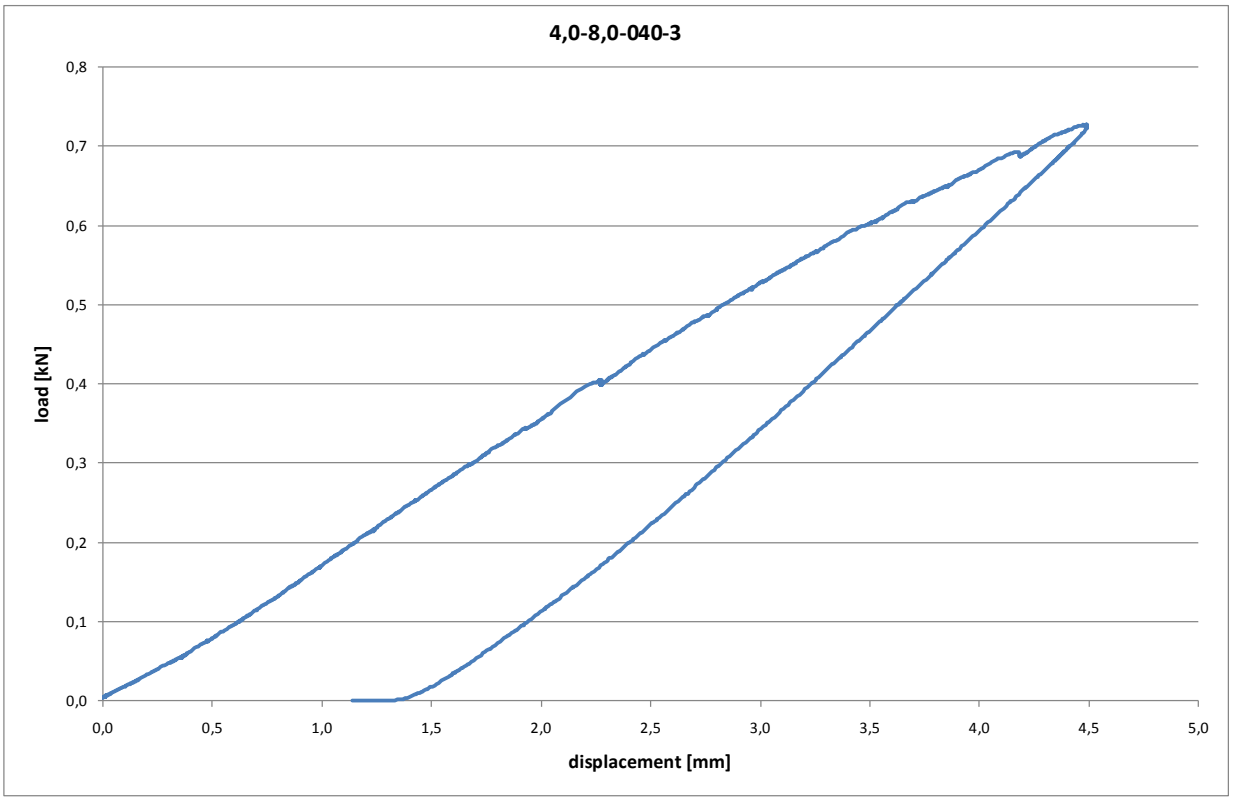
Thickness of substructure: 4,0 mm

Nominal diameter of fastener: 8,0 mm

Lever arm: 40 mm




4,0-8,0-040-2
load [kN]
displacement [mm]
0,0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
4,5
5,0

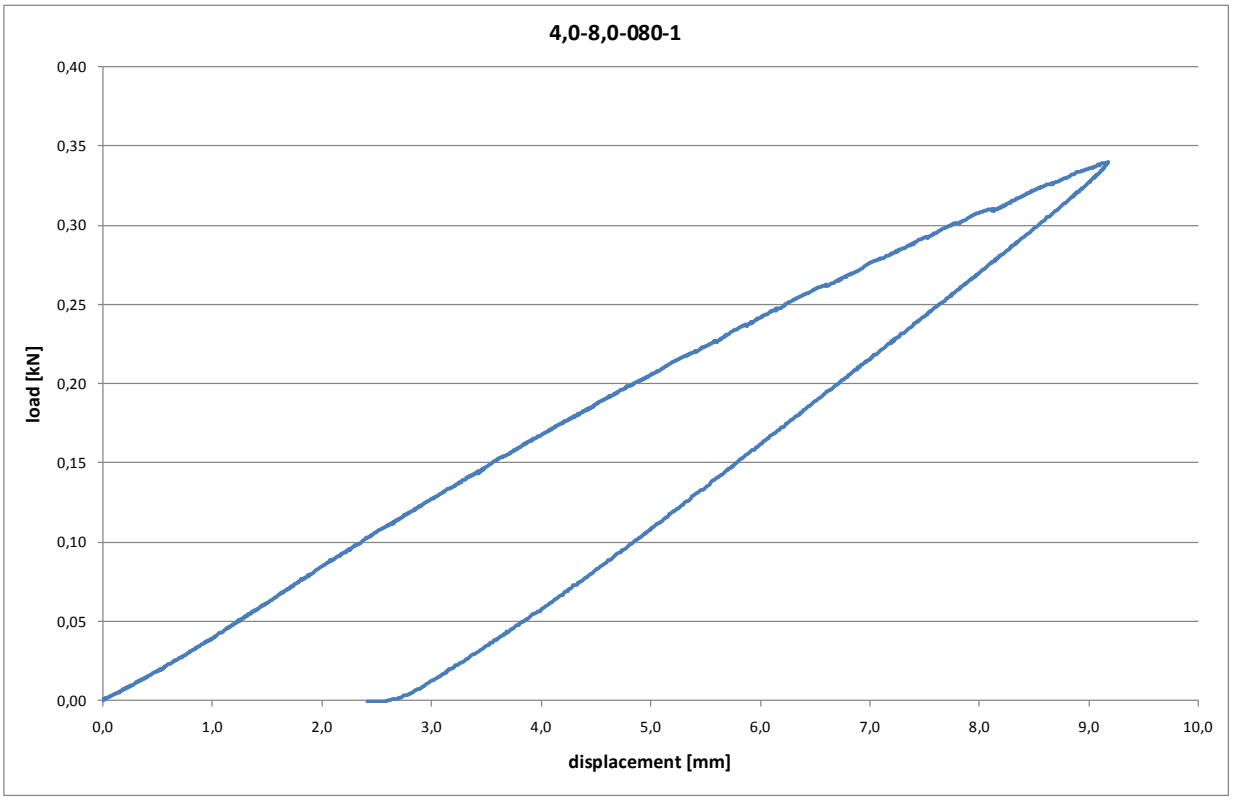

4,0-8,0-040-3
load [kN]
displacement [mm]
0,0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
4,5
5,0

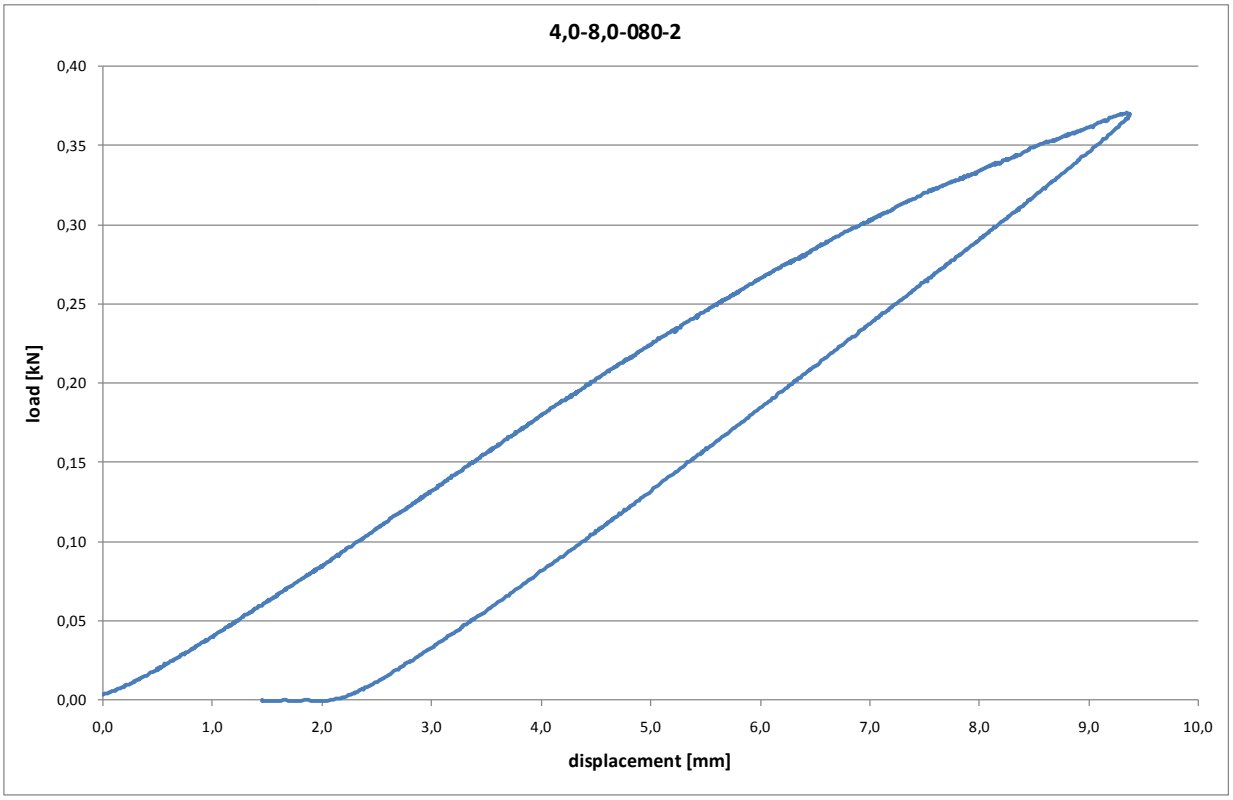
Bending tests

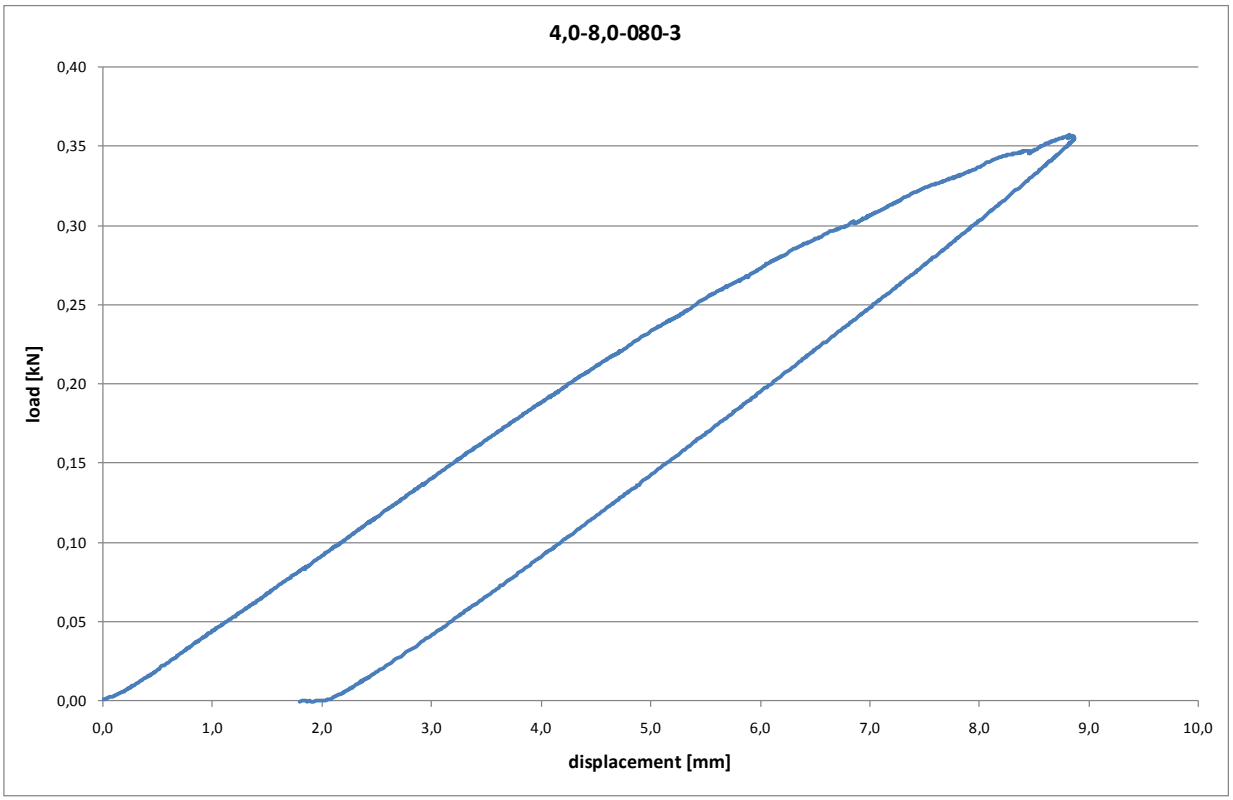
Thickness of substructure: 4,0 mm

Nominal diameter of fastener: 8,0 mm

Lever arm: 80 mm




4,0-8,0-080-2
load [kN]
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0
8,0
9,0
10,0
displacement [mm]

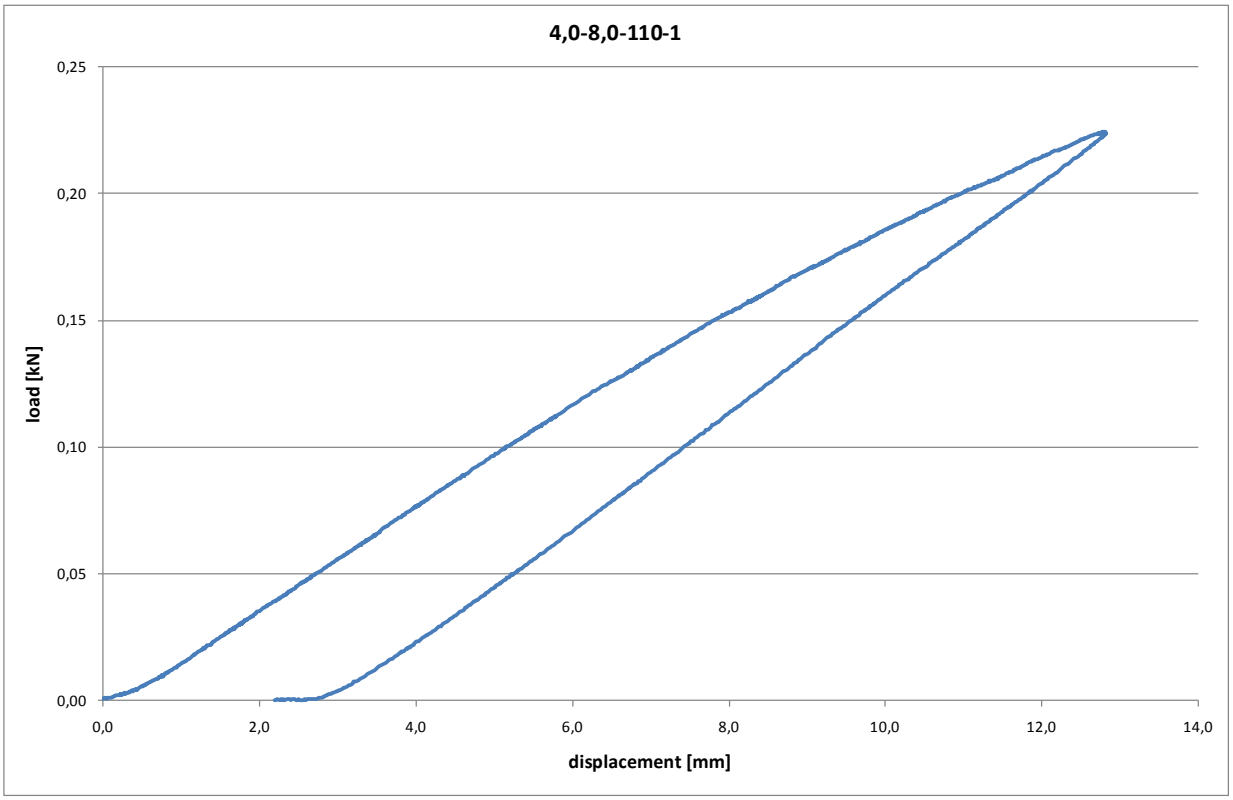

4,0-8,0-080-3
load [kN]
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0
8,0
9,0
10,0
displacement [mm]

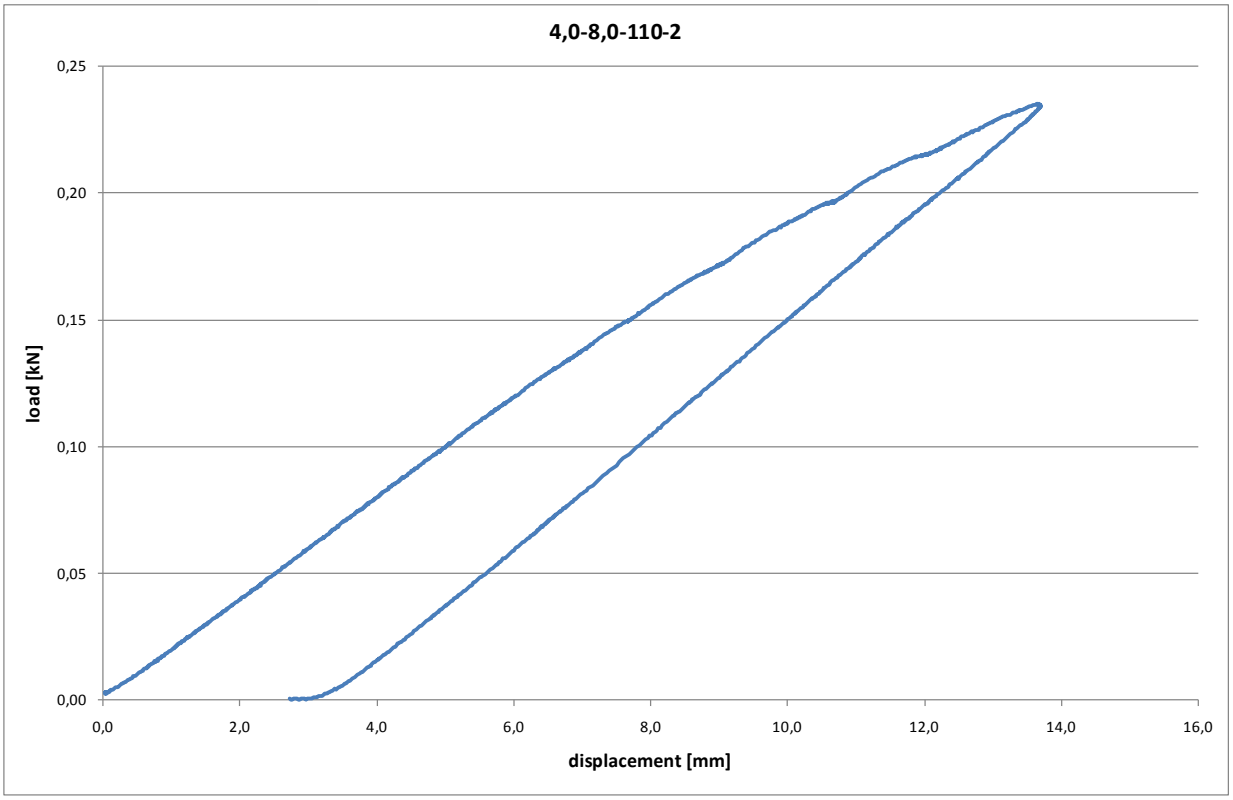
Bending tests

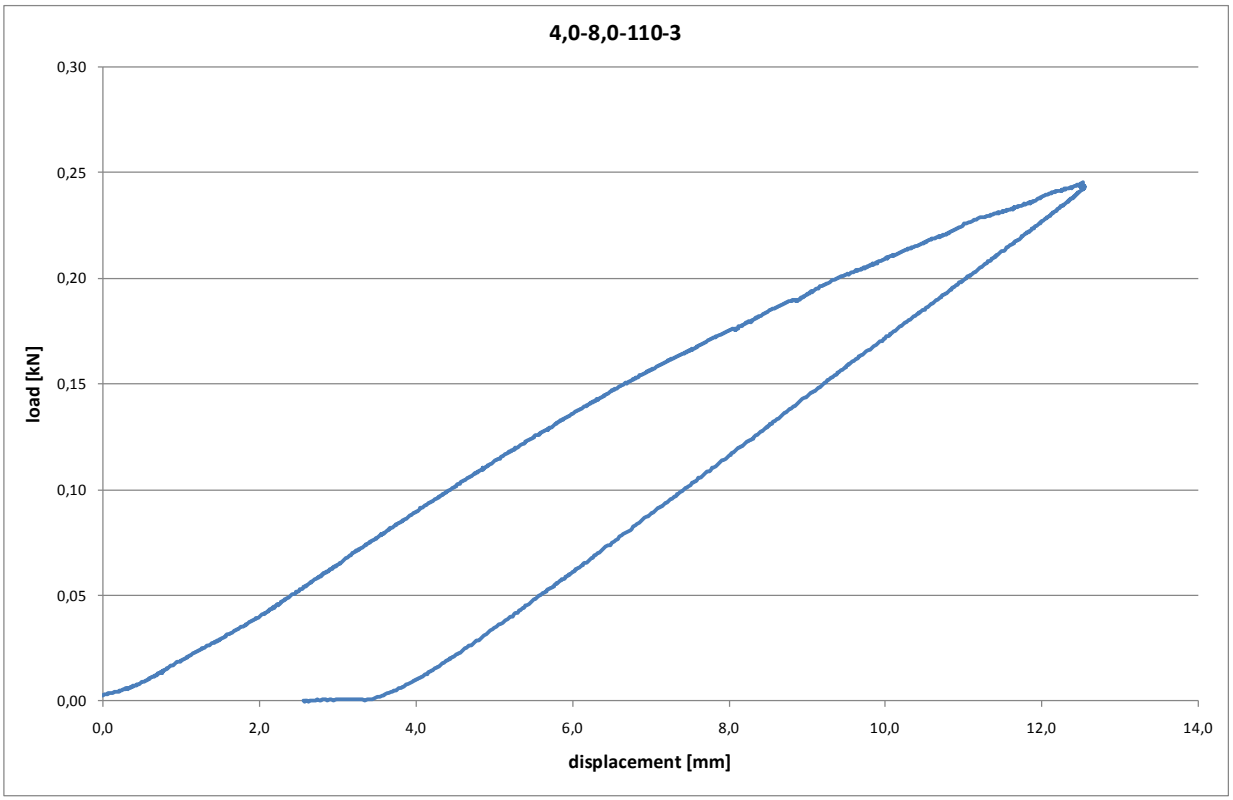
Thickness of substructure: 4,0 mm

Nominal diameter of fastener: 8,0 mm

Lever arm: 110 mm




4,0-8,0-110-2
load [kN]
0,25
0,20
0,15
0,10
0,05
0,00
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
displacement [mm]

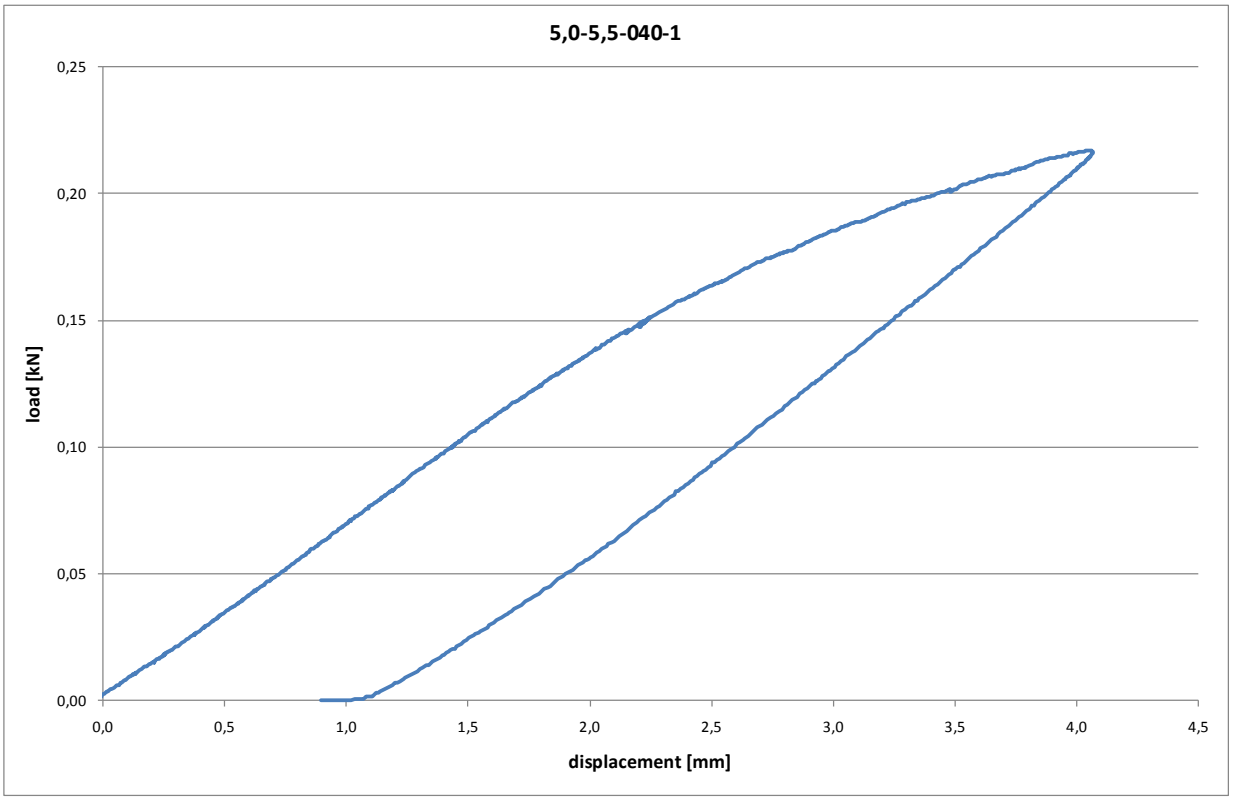

4,0-8,0-110-3
load [kN]
0,30
0,25
0,20
0,15
0,10
0,05
0,00
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
displacement [mm]

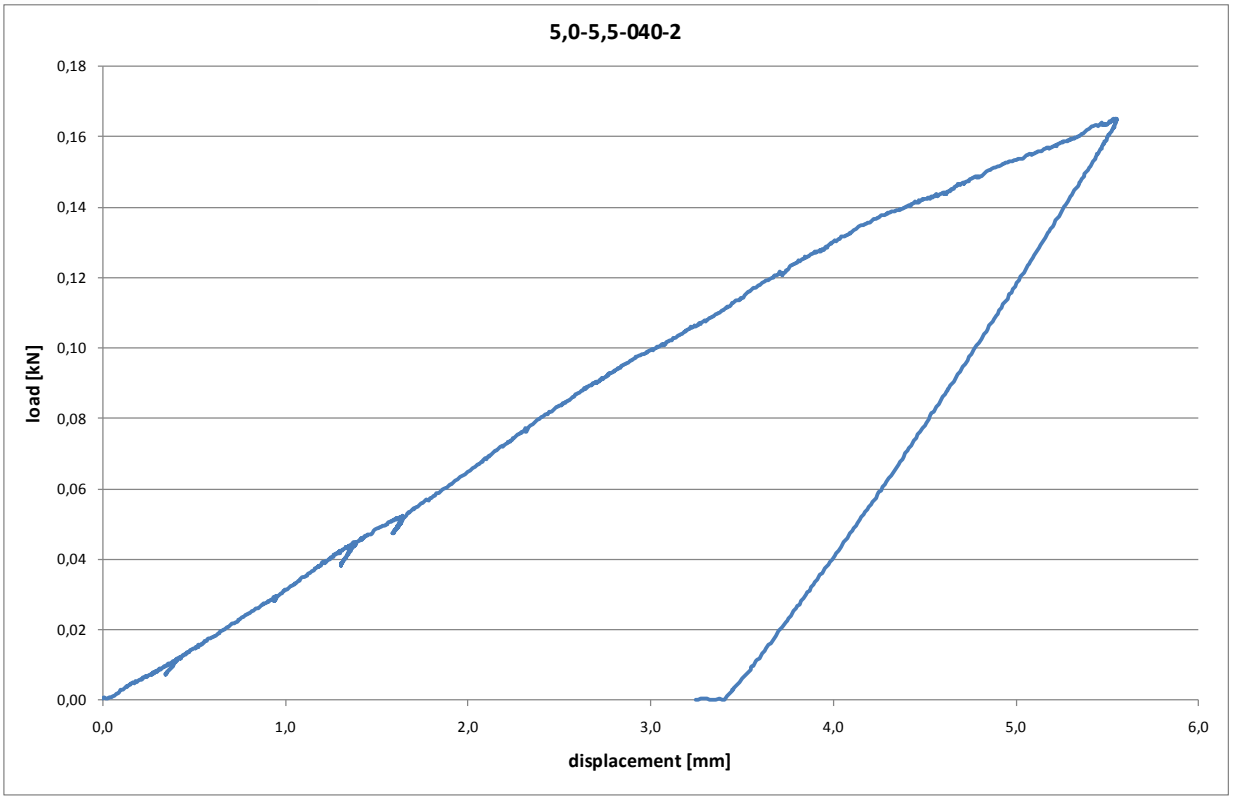
Bending tests

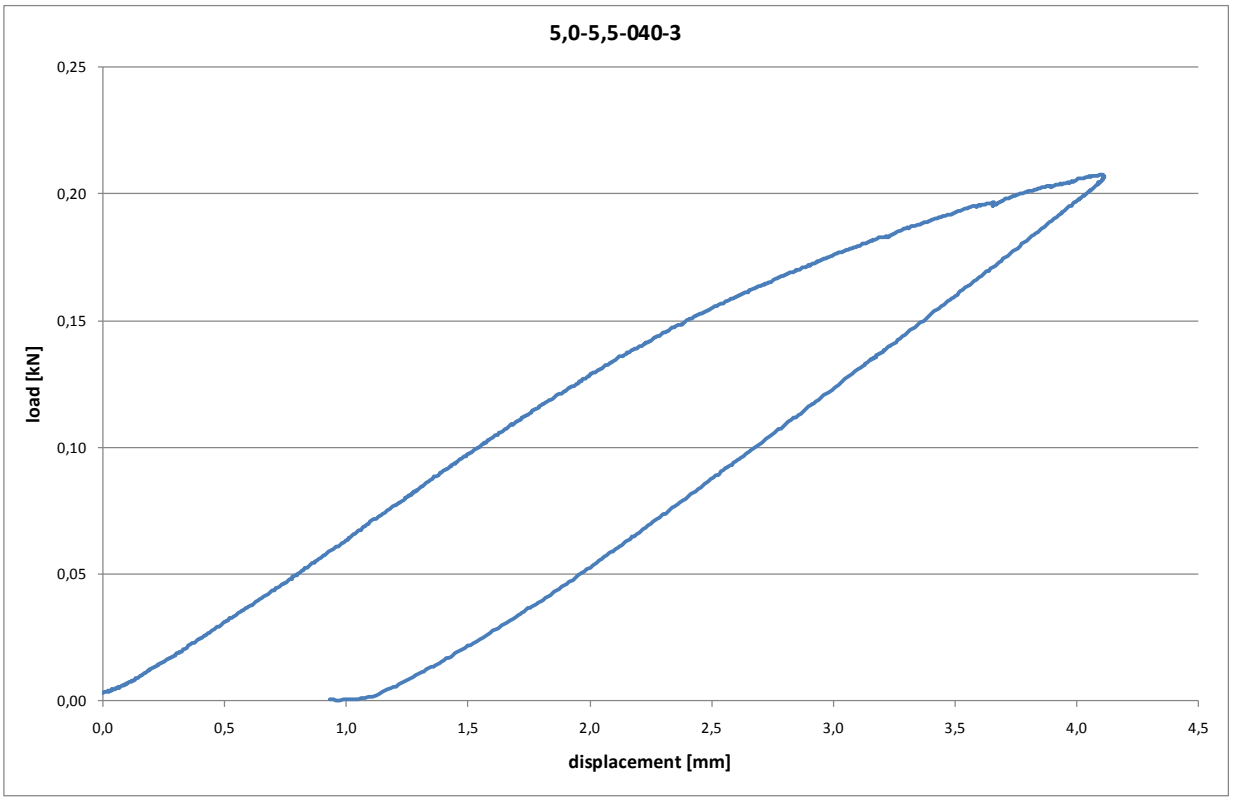
Thickness of substructure: 5,0 mm

Nominal diameter of fastener: 5,5 mm

Lever arm: 40 mm




5,0-5,5-040-2
load [kN]
0,18
0,16
0,14
0,12
0,10
0,08
0,06
0,04
0,02
0,00
0,0
1,0
2,0
3,0
4,0
5,0
6,0
displacement [mm]

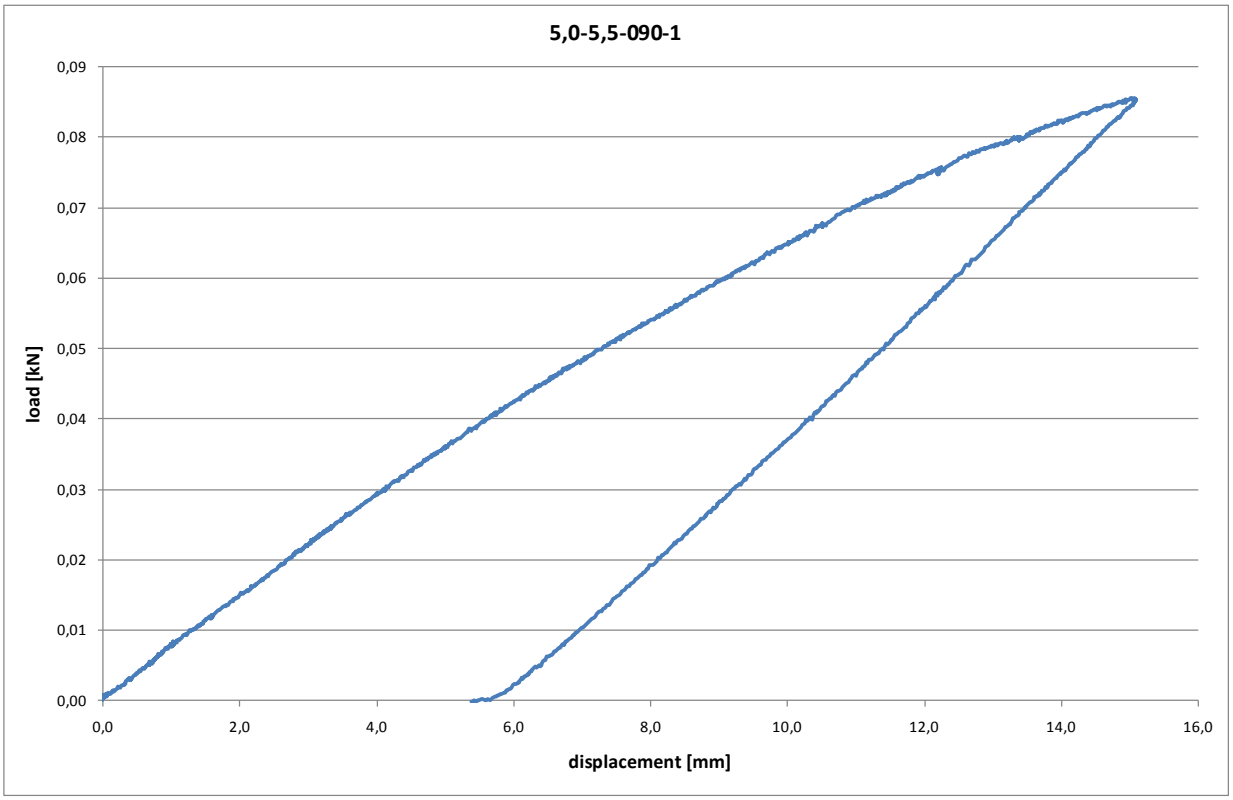

5,0-5,5-040-3
load [kN]
0,25
0,20
0,15
0,10
0,05
0,00
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
4,5
displacement [mm]

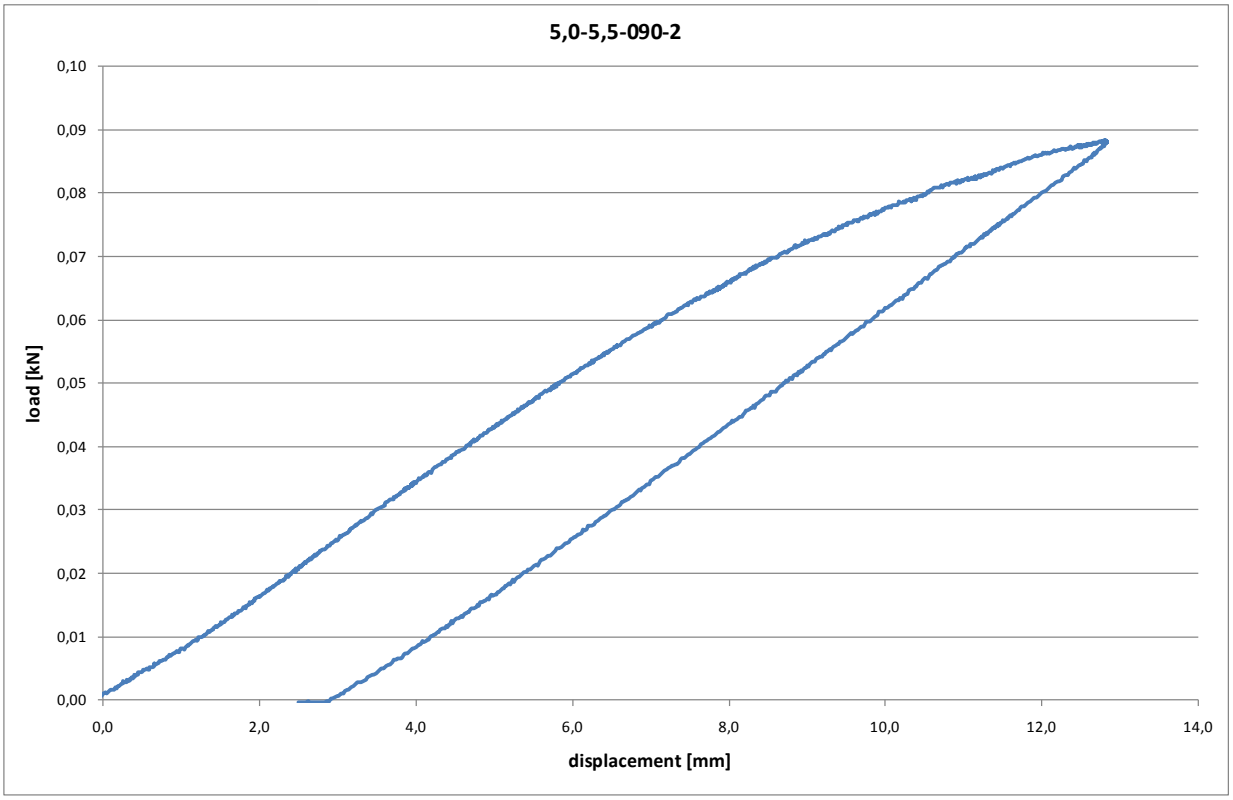
Bending tests

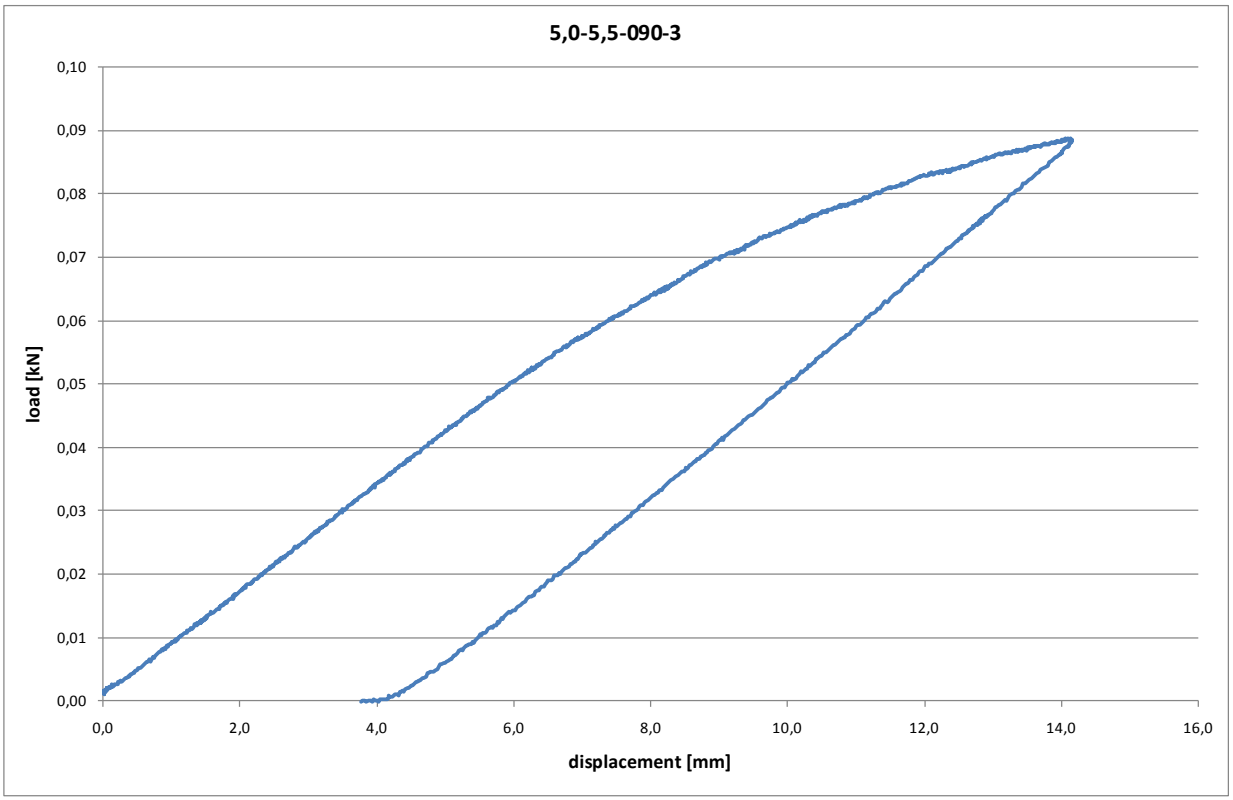
Thickness of substructure: 5,0 mm

Nominal diameter of fastener: 5,5 mm

Lever arm: 90 mm




5,0-5,5-090-2
load [kN]
0,10
0,09
0,08
0,07
0,06
0,05
0,04
0,03
0,02
0,01
0,00
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
displacement [mm]

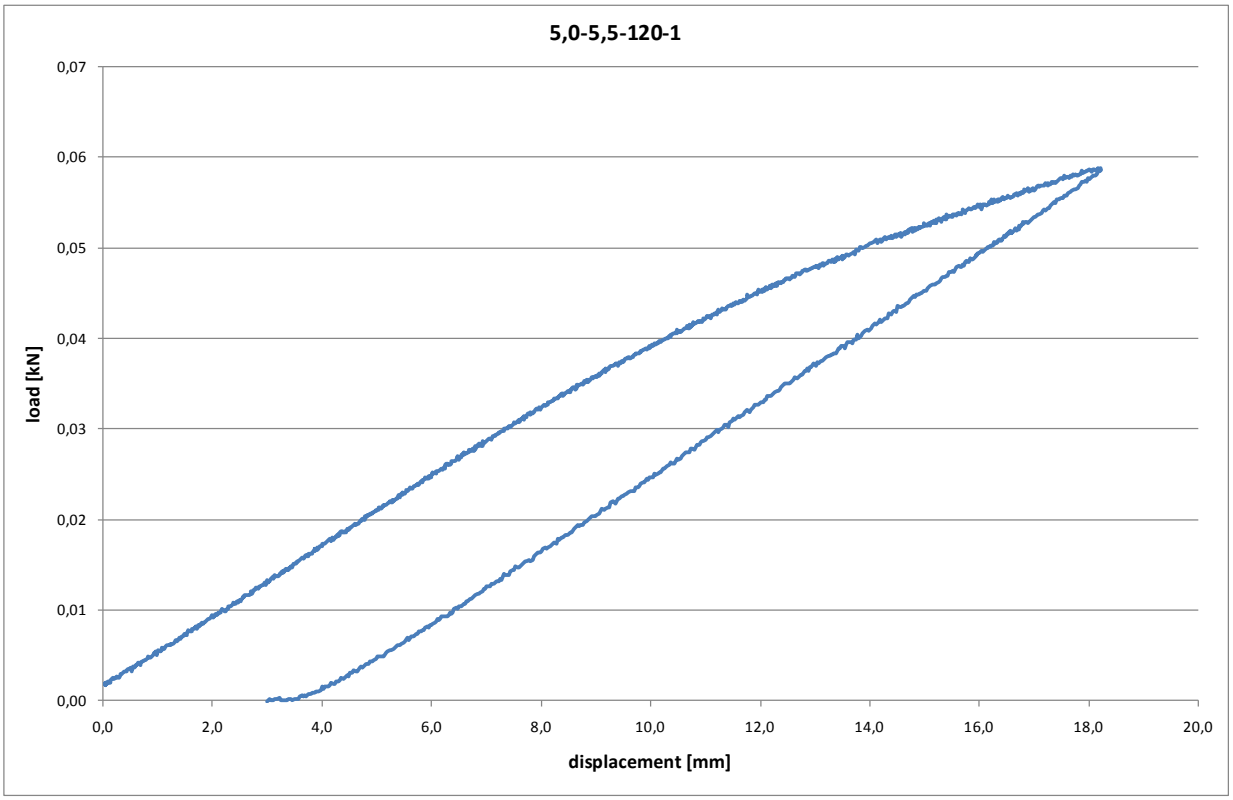

5,0-5,5-090-3
load [kN]
0,10
0,09
0,08
0,07
0,06
0,05
0,04
0,03
0,02
0,01
0,00
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
displacement [mm]

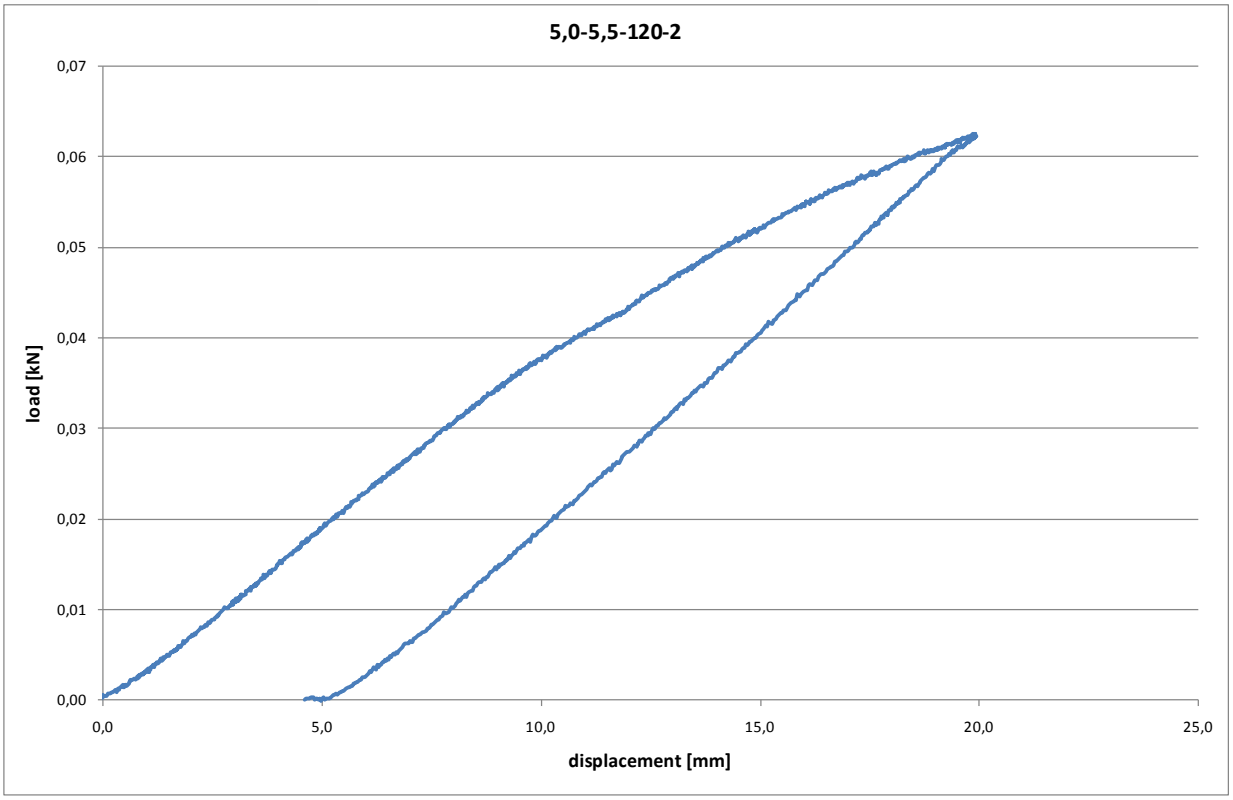
Bending tests

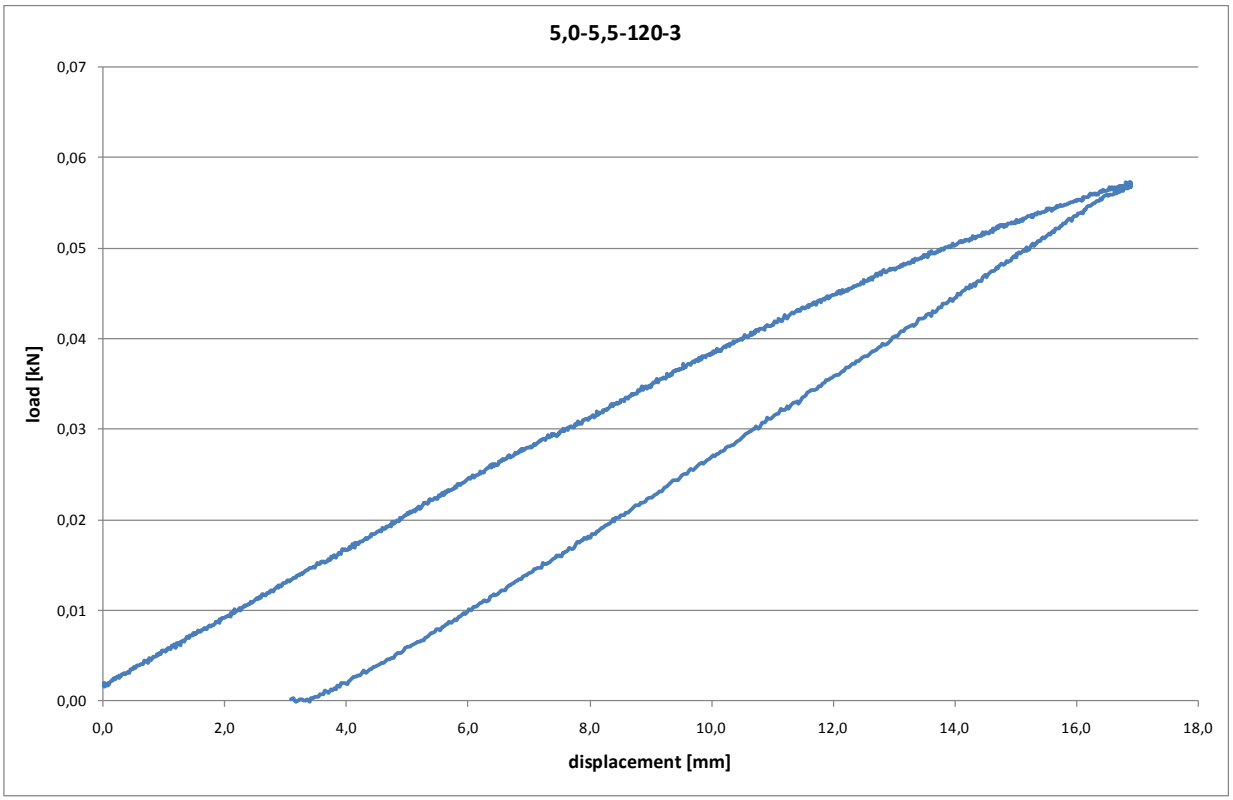
Thickness of substructure: 5,0 mm

Nominal diameter of fastener: 5,5 mm

Lever arm: 120 mm




5,0-5,5-120-2
load [kN]
0,07
0,06
0,05
0,04
0,03
0,02
0,01
0,00
0,0
5,0
10,0
15,0
20,0
25,0
displacement [mm]

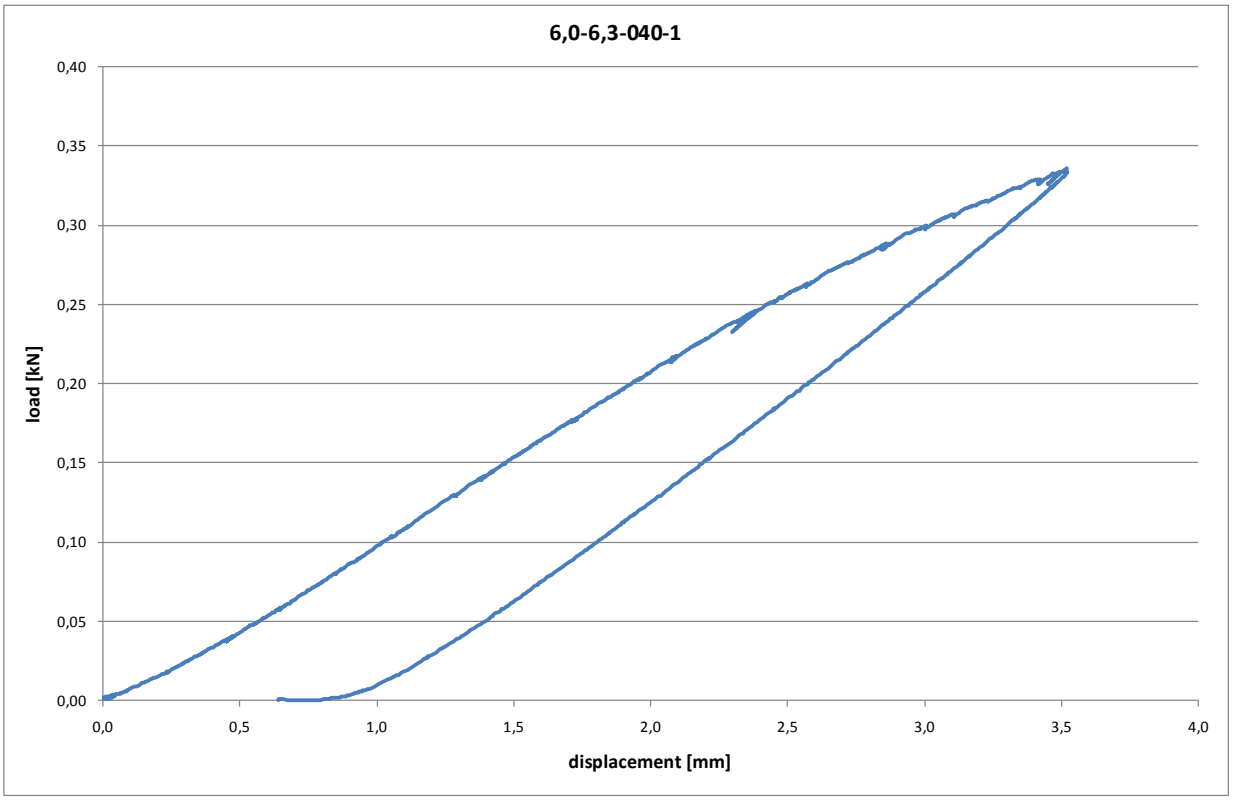

5,0-5,5-120-3
load [kN]
0,07
0,06
0,05
0,04
0,03
0,02
0,01
0,00
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
18,0
displacement [mm]

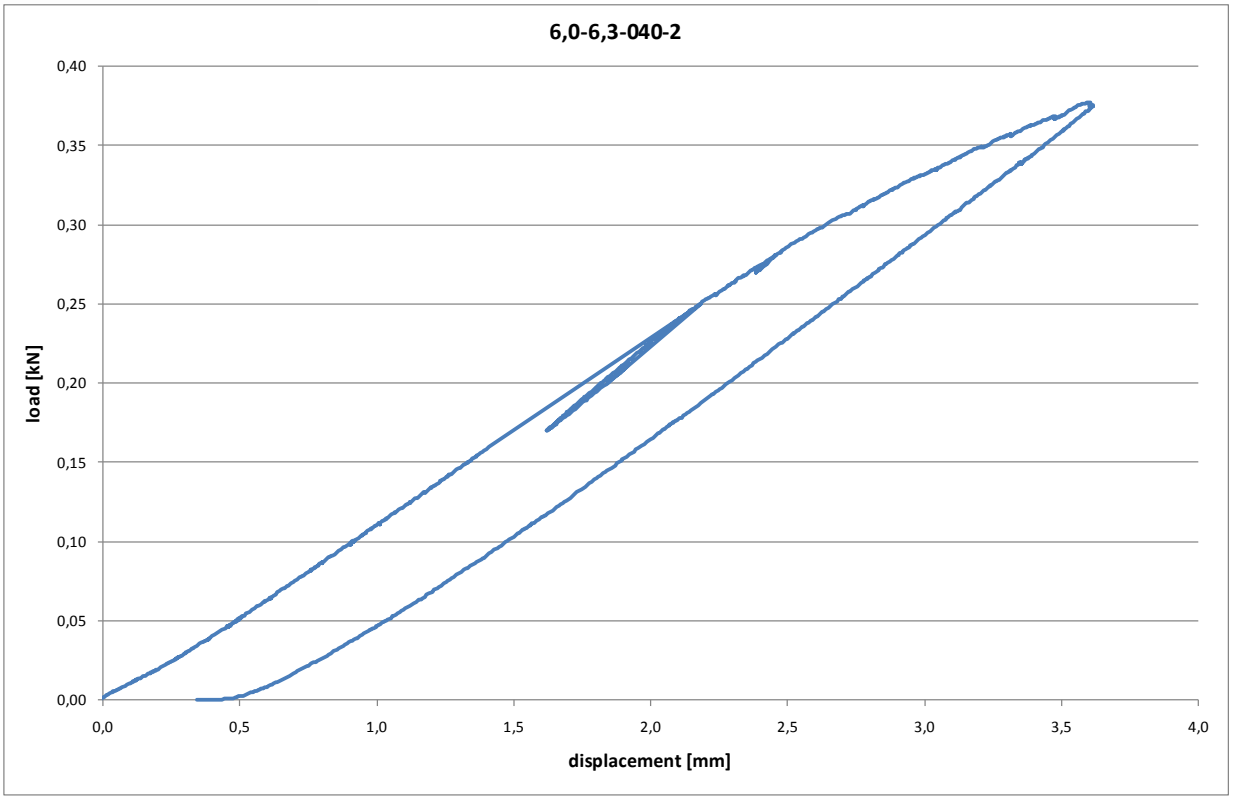
Bending tests

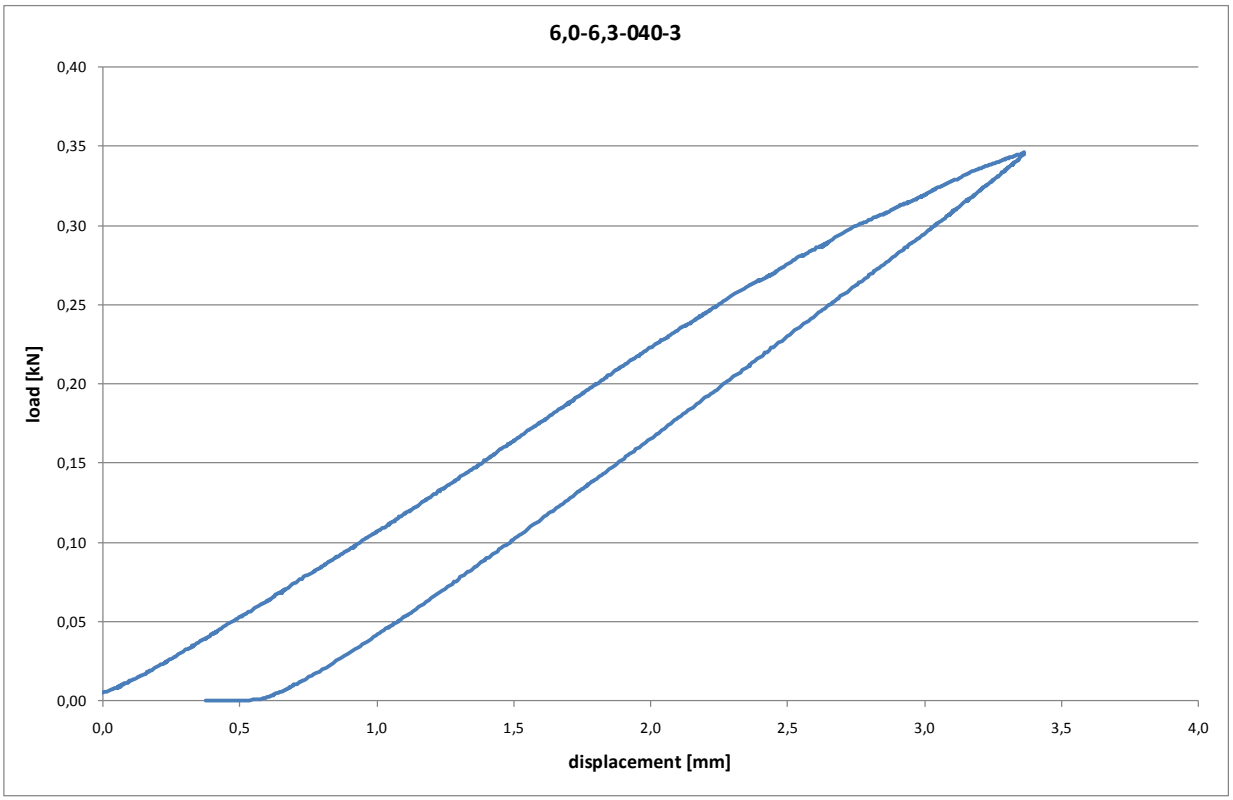
Thickness of substructure: 6,0 mm

Nominal diameter of fastener: 6,3 mm

Lever arm: 40 mm




6,0-6,3-040-2
load [kN]
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
displacement [mm]

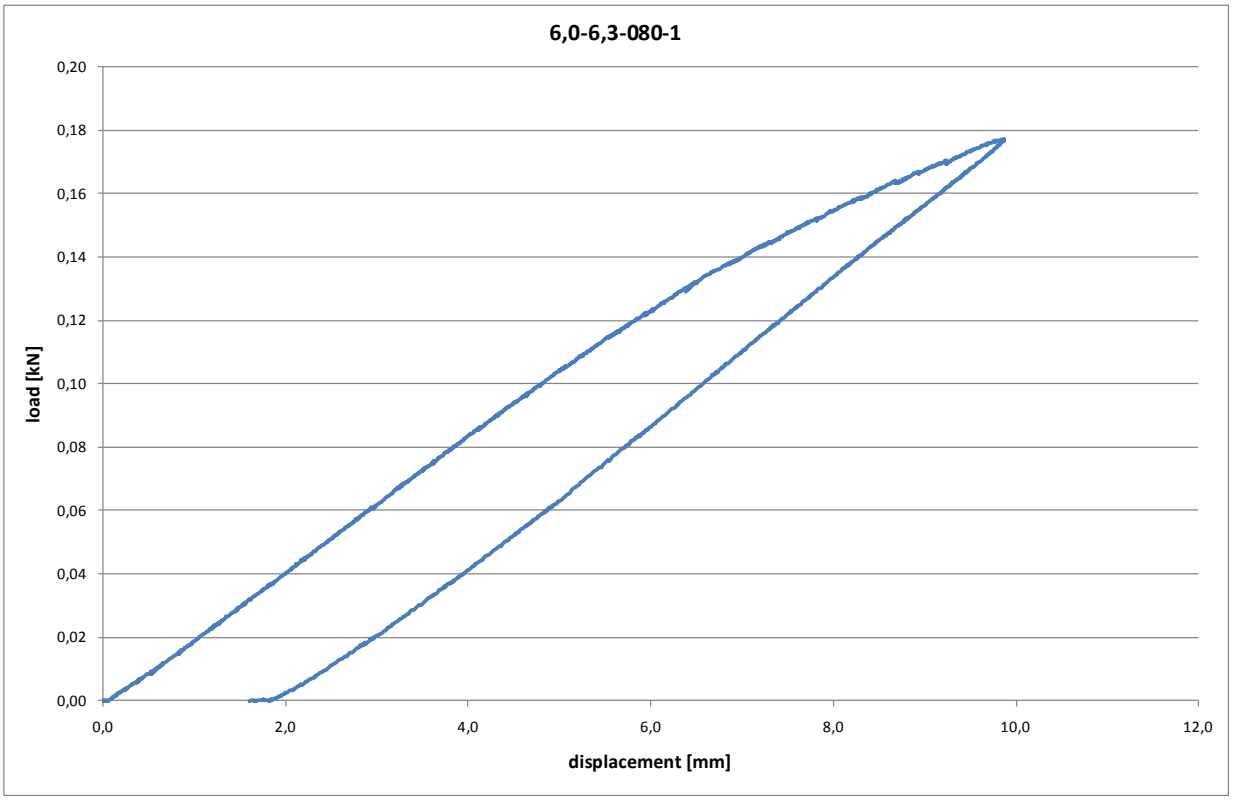

6,0-6,3-040-3
load [kN]
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
displacement [mm]

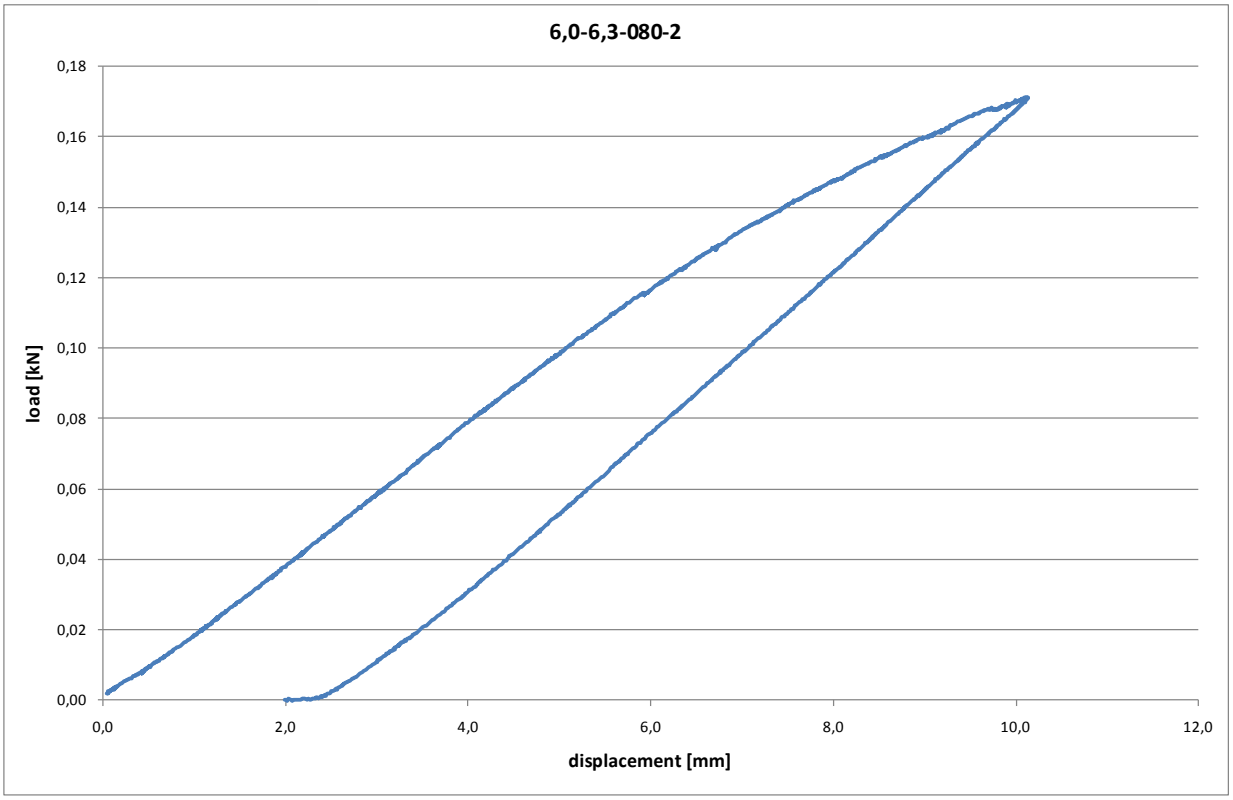
Bending tests

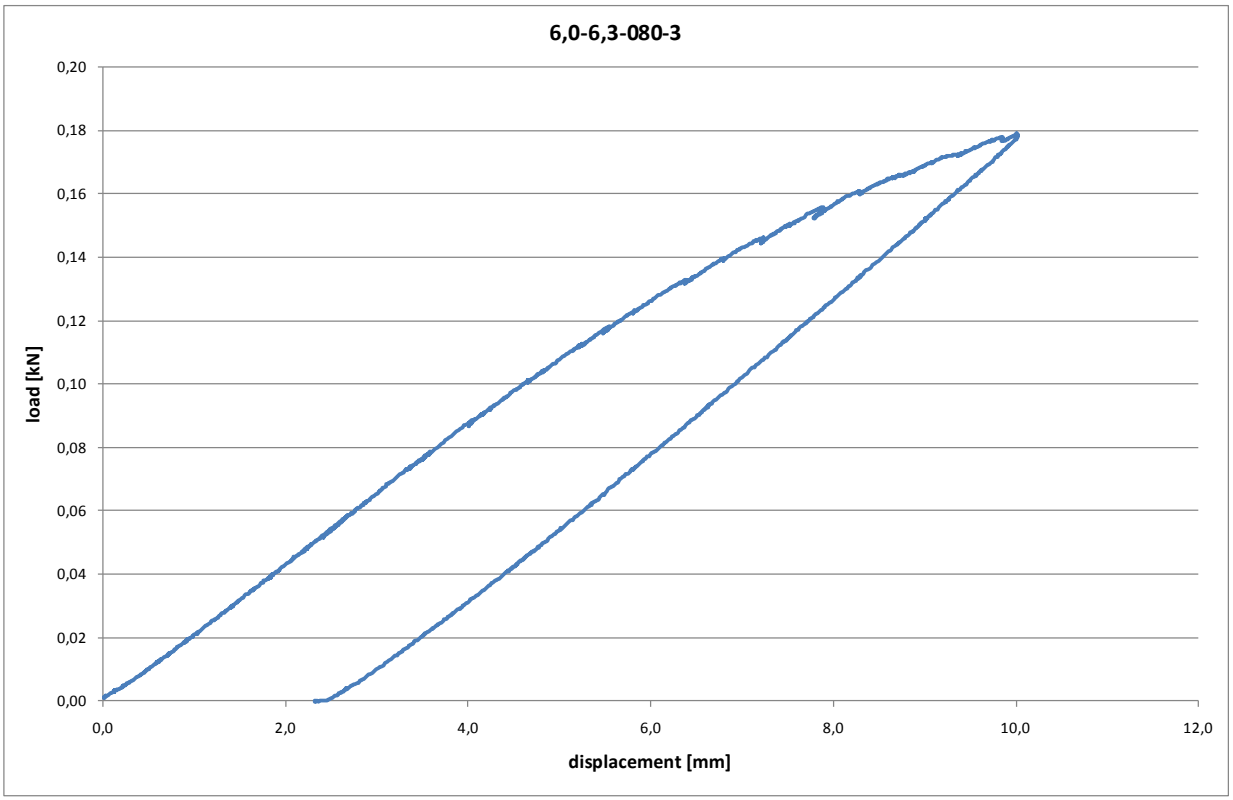
Thickness of substructure: 6,0 mm

Nominal diameter of fastener: 6,3 mm

Lever arm: 80 mm




6,0-6,3-080-2
load [kN]
0,18
0,16
0,14
0,12
0,10
0,08
0,06
0,04
0,02
0,00
0,0
2,0
4,0
6,0
8,0
10,0
12,0
displacement [mm]

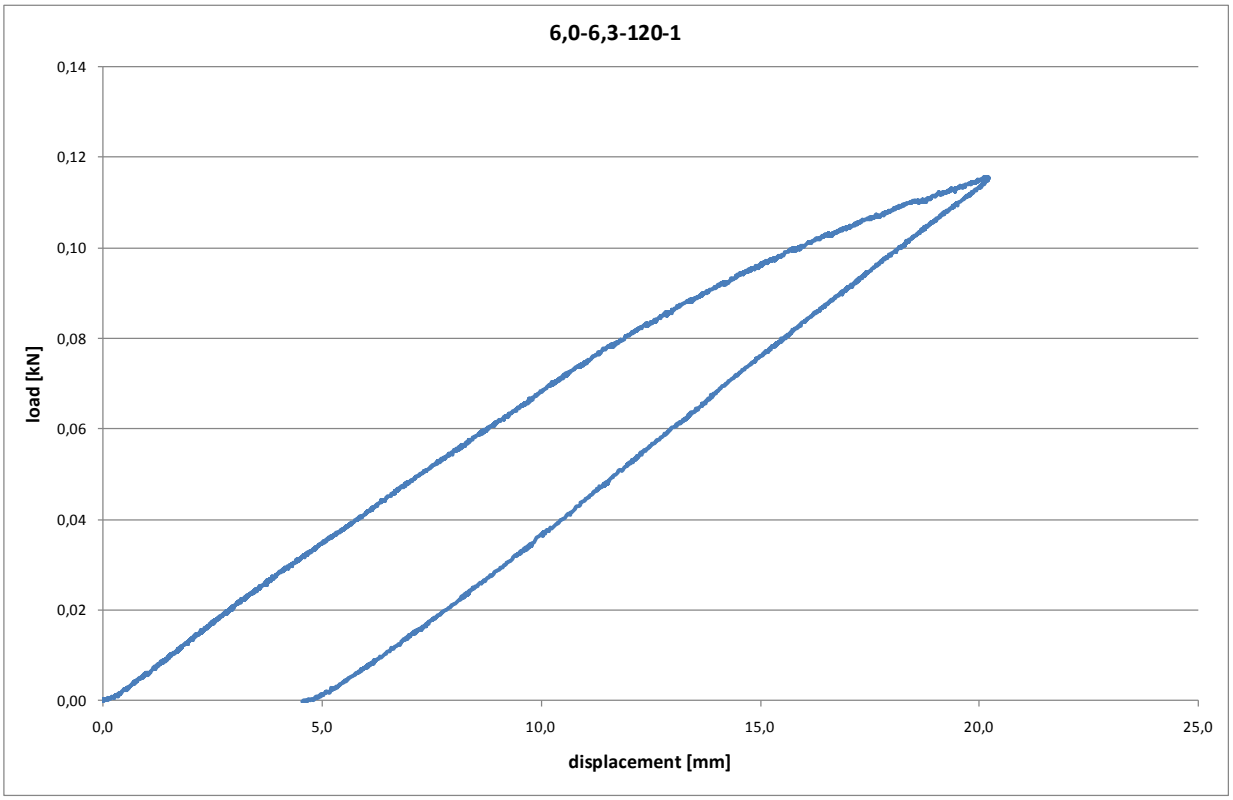

6,0-6,3-080-3
load [kN]
0,20
0,18
0,16
0,14
0,12
0,10
0,08
0,06
0,04
0,02
0,00
0,0
2,0
4,0
6,0
8,0
10,0
12,0
displacement [mm]

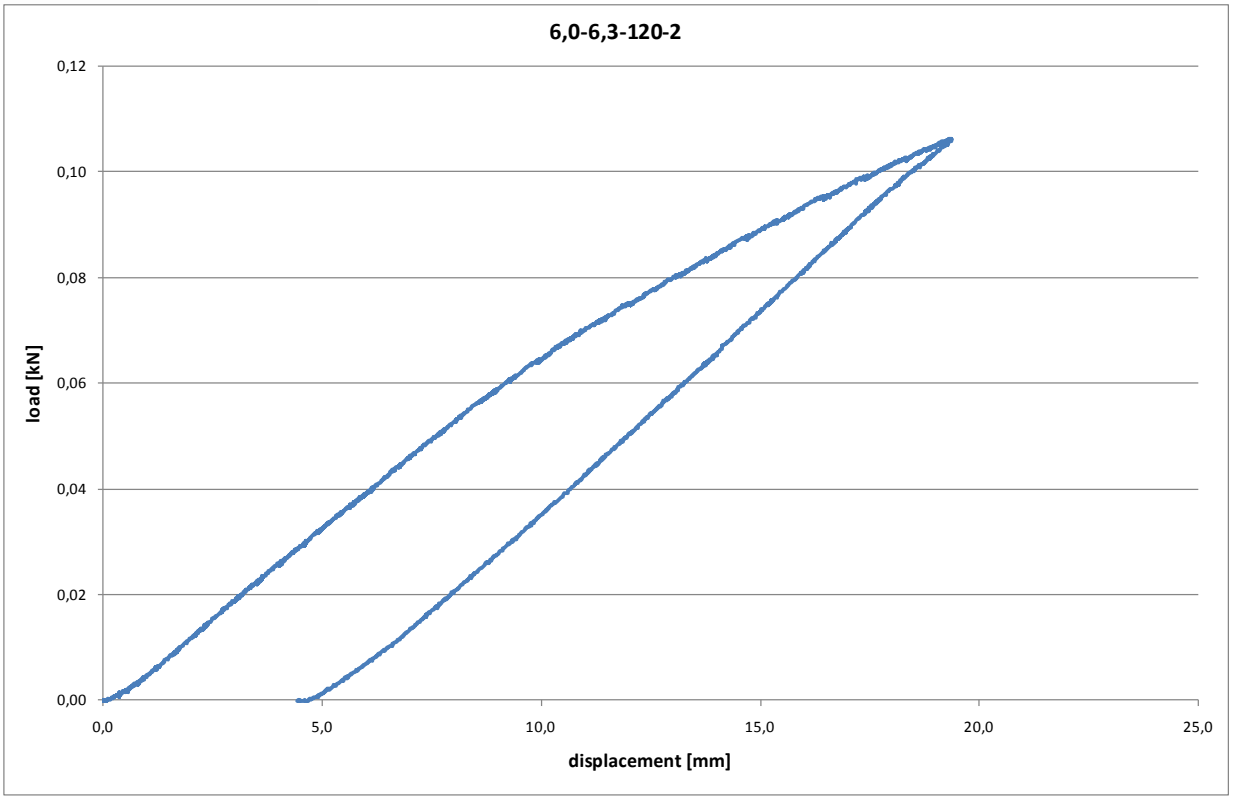
Bending tests

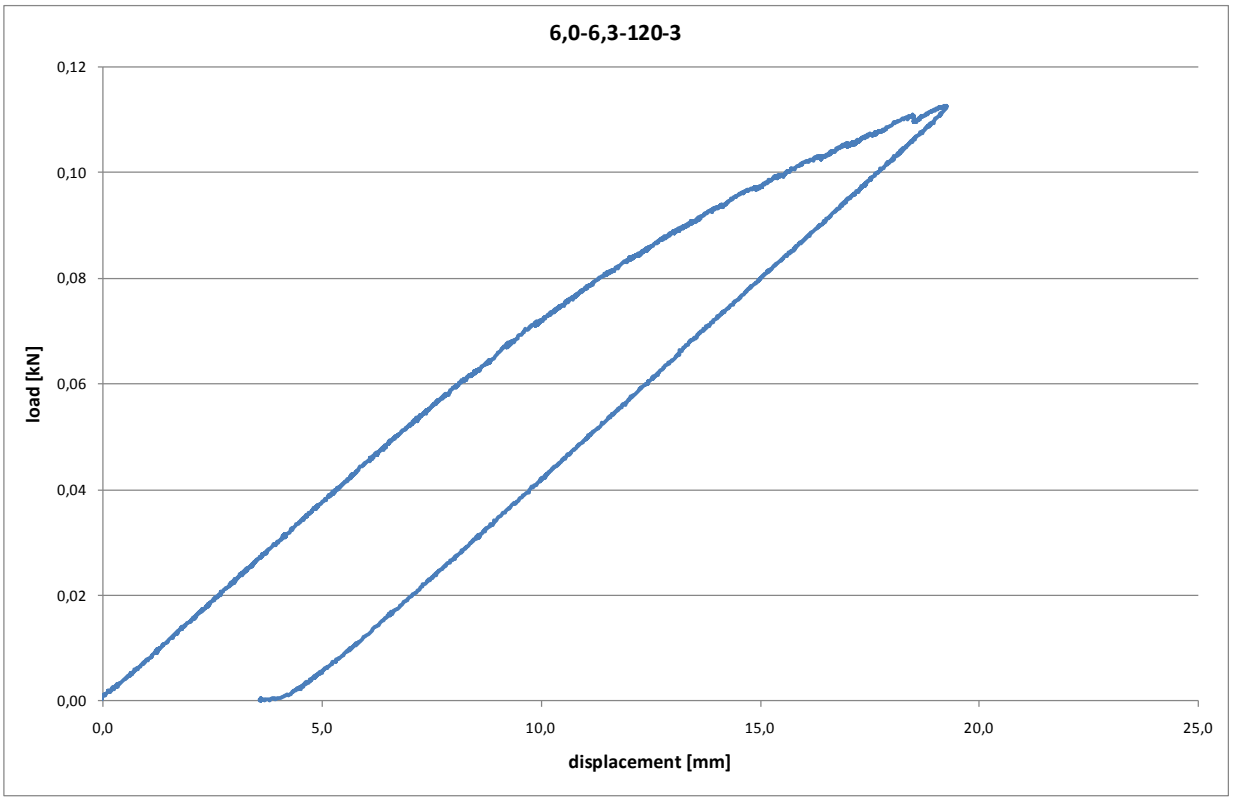
Thickness of substructure: 6,0 mm

Nominal diameter of fastener: 6,3 mm

Lever arm: 120 mm




6,0-6,3-120-2
load [kN]
0,12
0,10
0,08
0,06
0,04
0,02
0,00
0,0
5,0
10,0
15,0
20,0
25,0
displacement [mm]

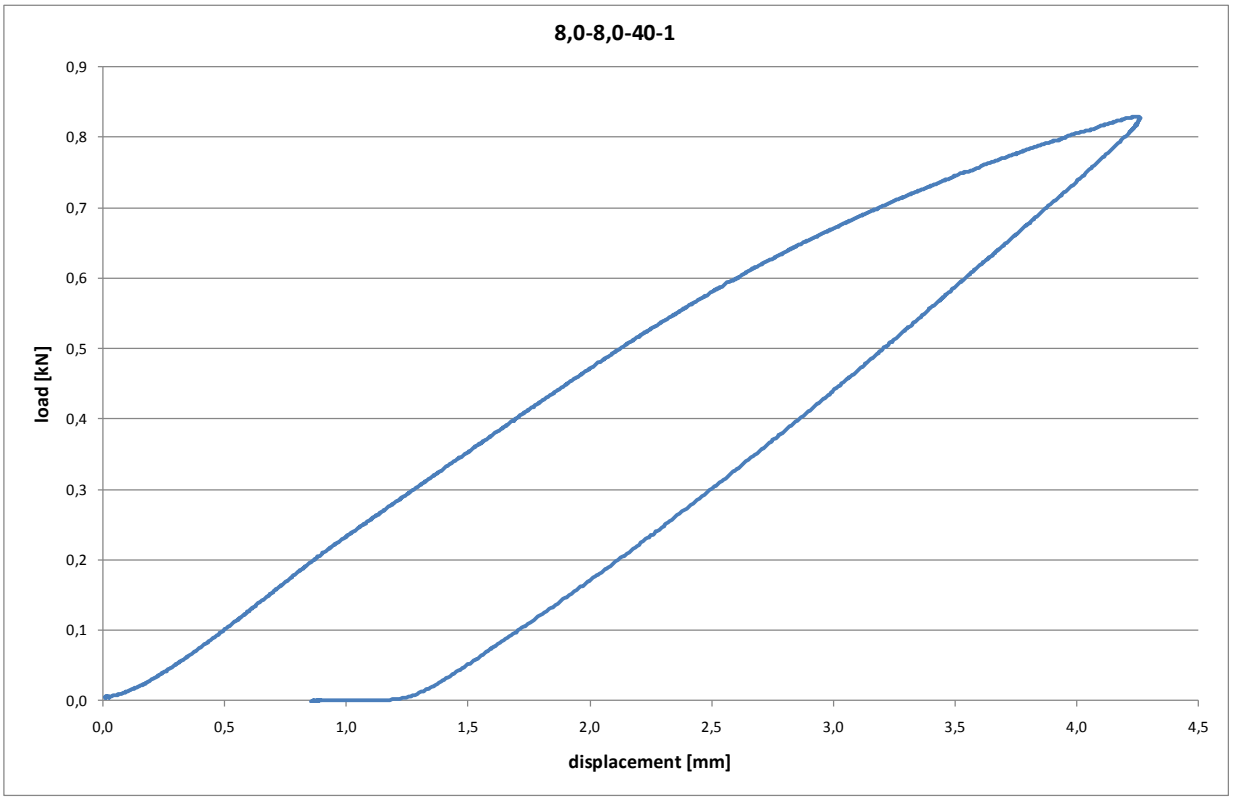

6,0-6,3-120-3
load [kN]
0,12
0,10
0,08
0,06
0,04
0,02
0,00
0,0
5,0
10,0
15,0
20,0
25,0
displacement [mm]

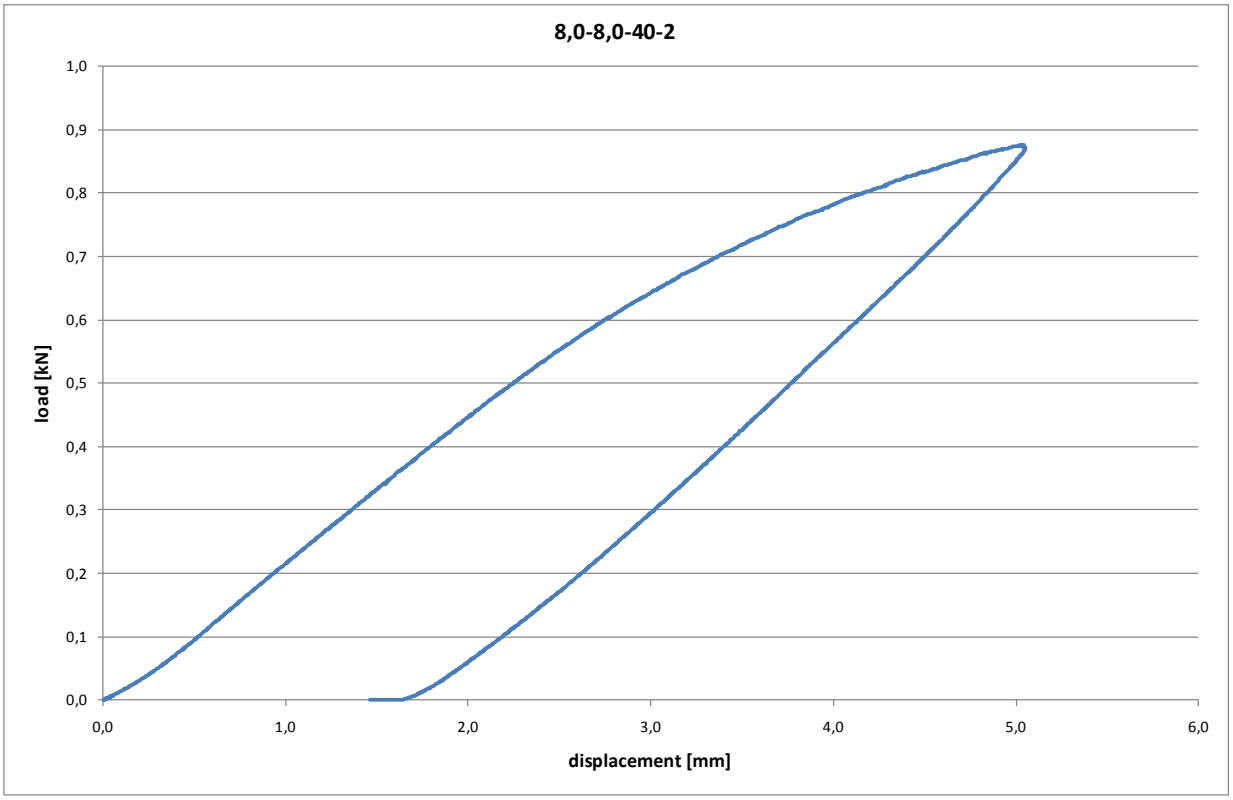
Bending tests

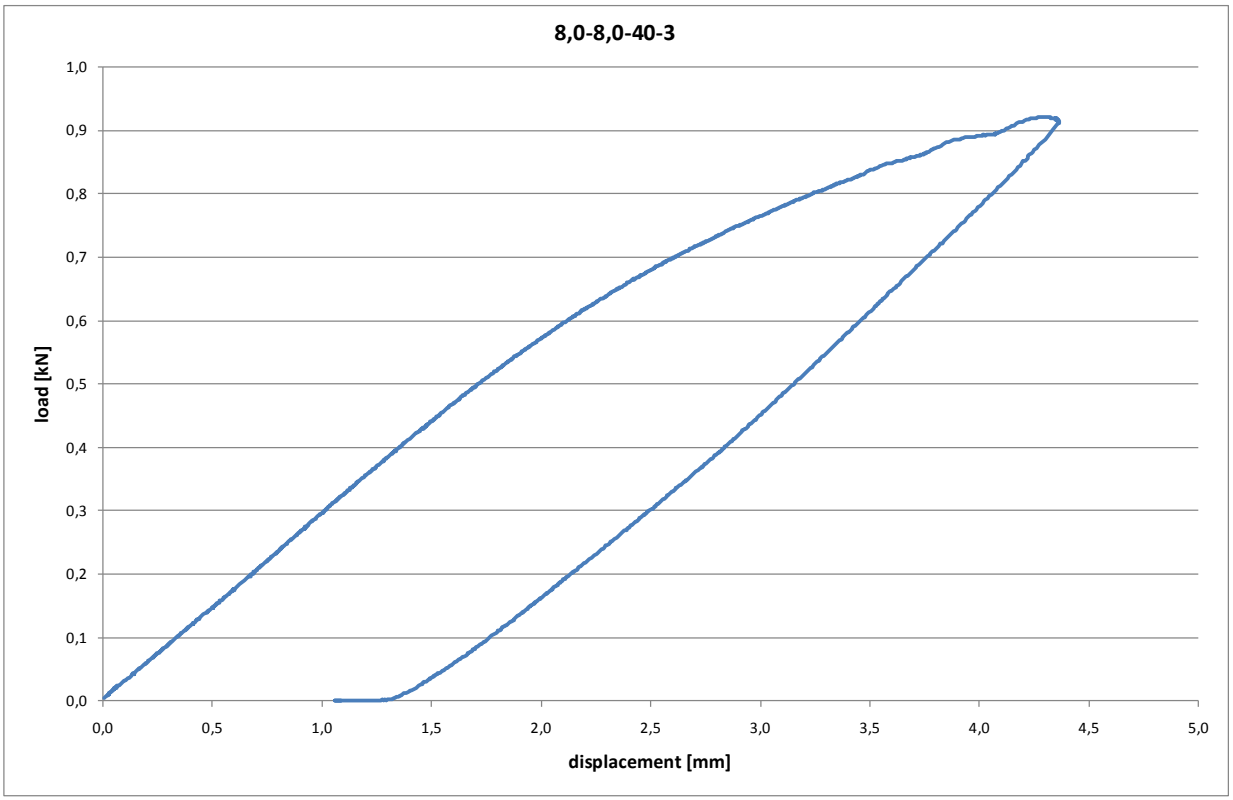
Thickness of substructure: 8,0 mm

Nominal diameter of fastener: 8,0 mm

Lever arm: 40 mm




8,0-8,0-40-2
load [kN]
displacement [mm]
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0

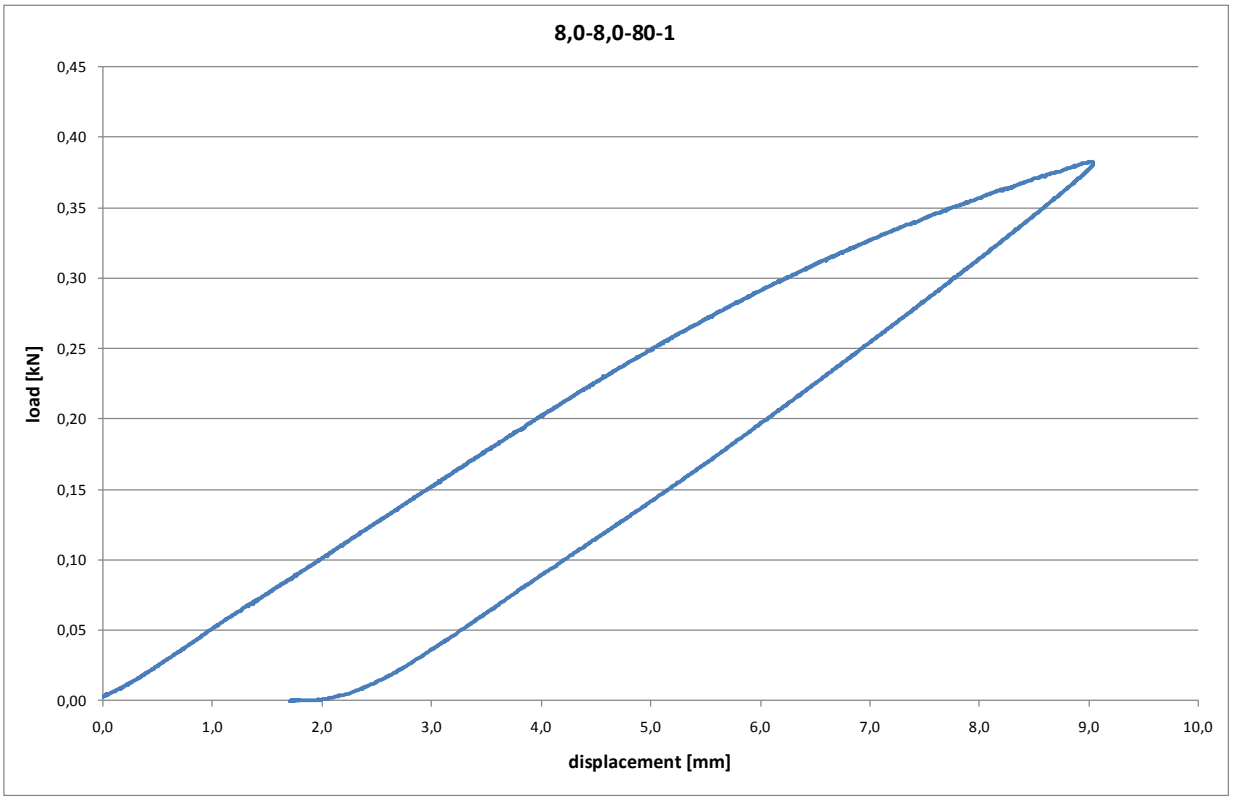

8,0-8,0-40-3
load [kN]
displacement [mm]
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
4,5
5,0

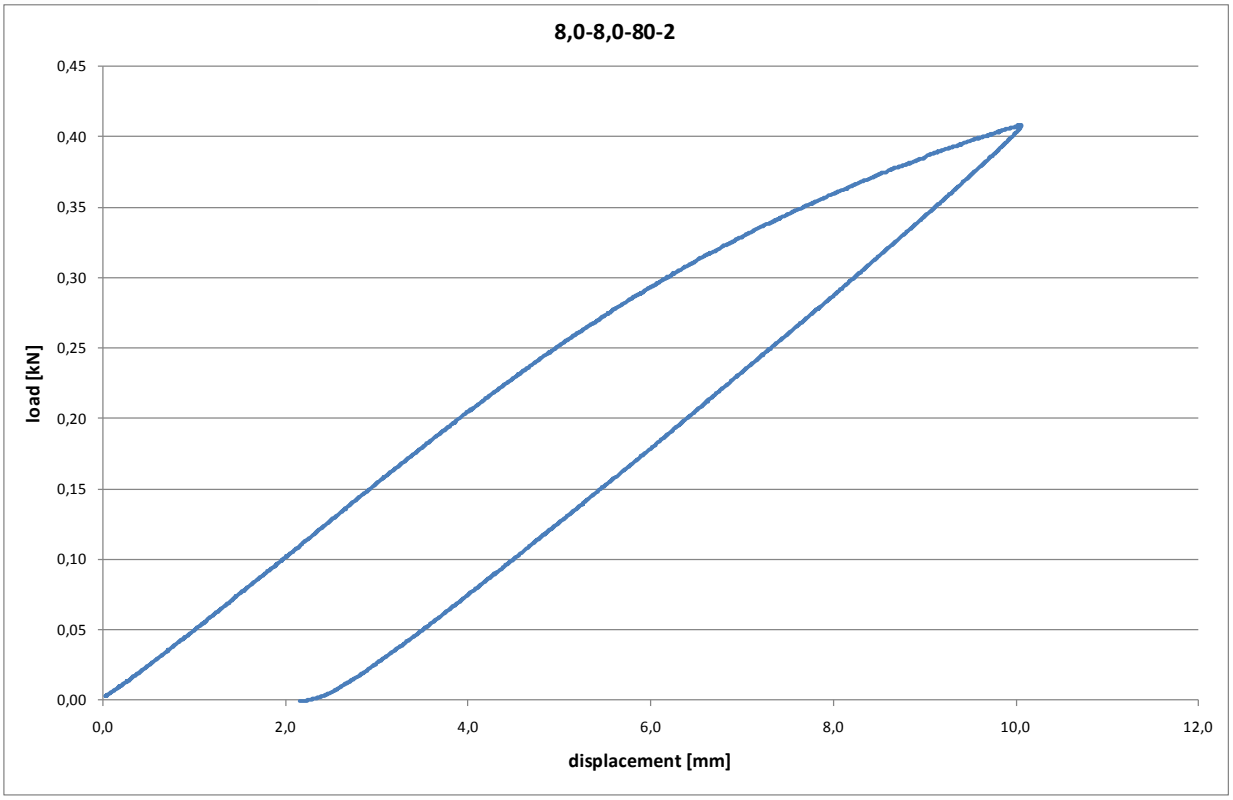
Bending tests

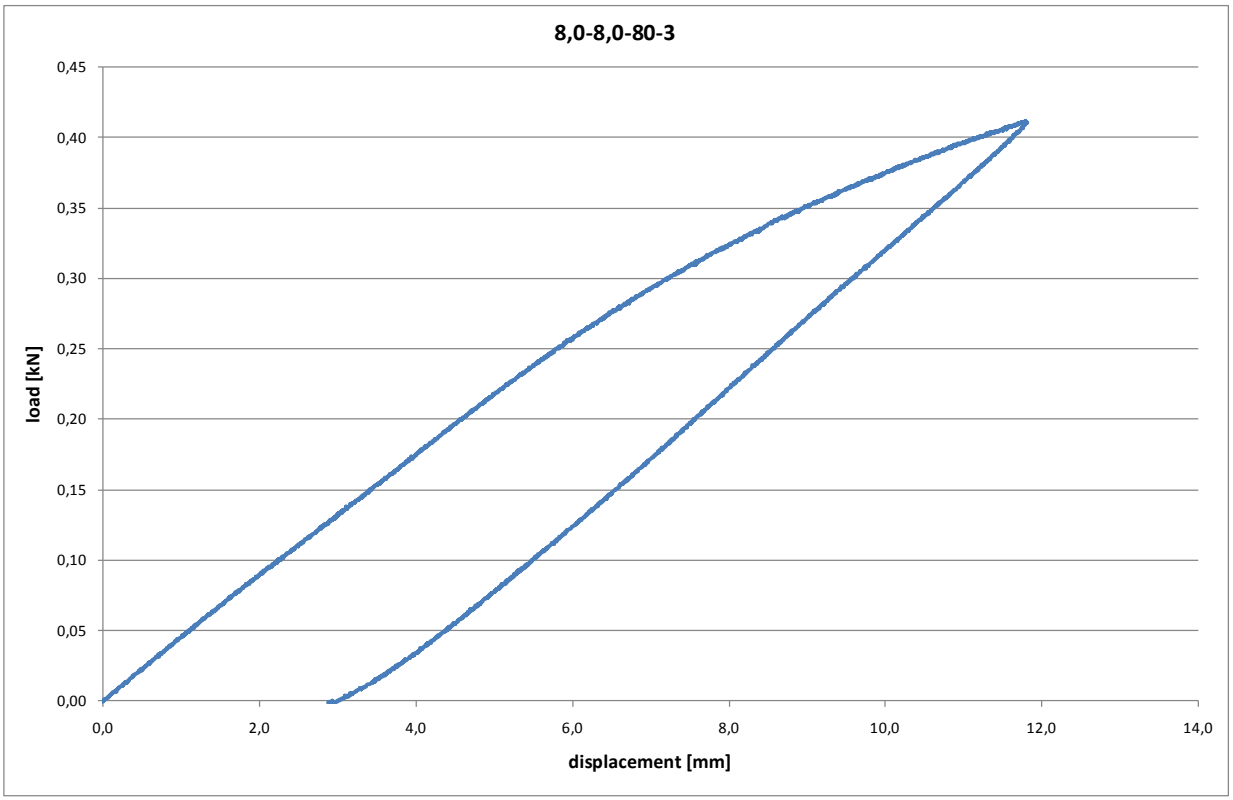
Thickness of substructure: 8,0 mm

Nominal diameter of fastener: 8,0 mm

Lever arm: 80 mm




8,0-8,0-80-2
load [kN]
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
0,0
2,0
4,0
6,0
8,0
10,0
12,0
displacement [mm]

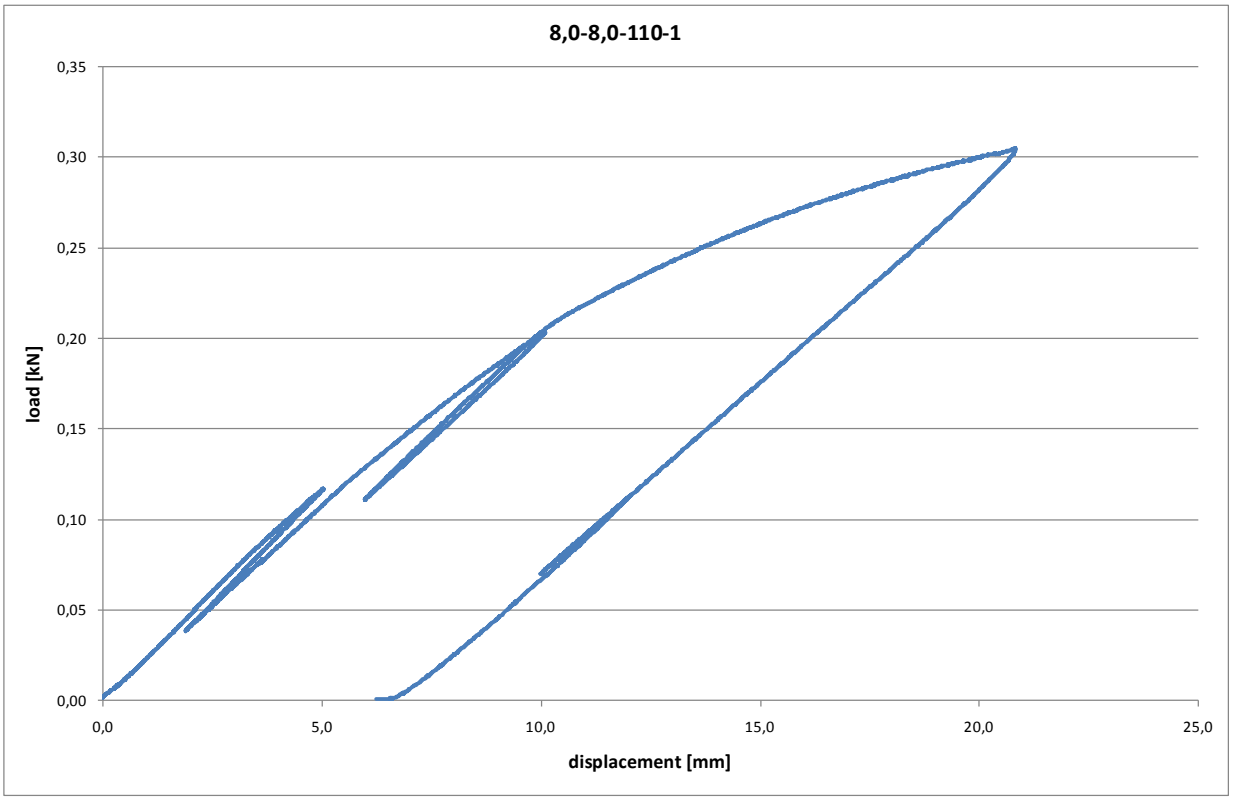

8,0-8,0-80-3
load [kN]
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
displacement [mm]

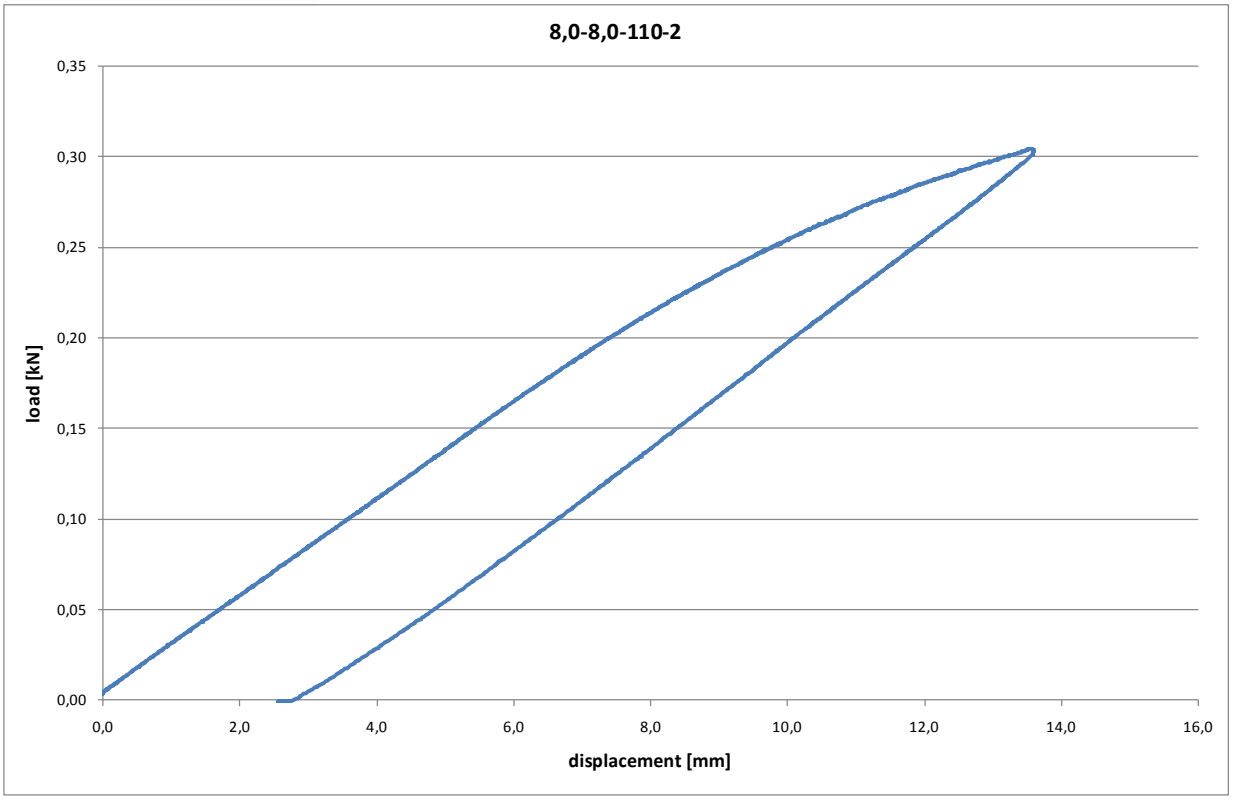
Bending tests

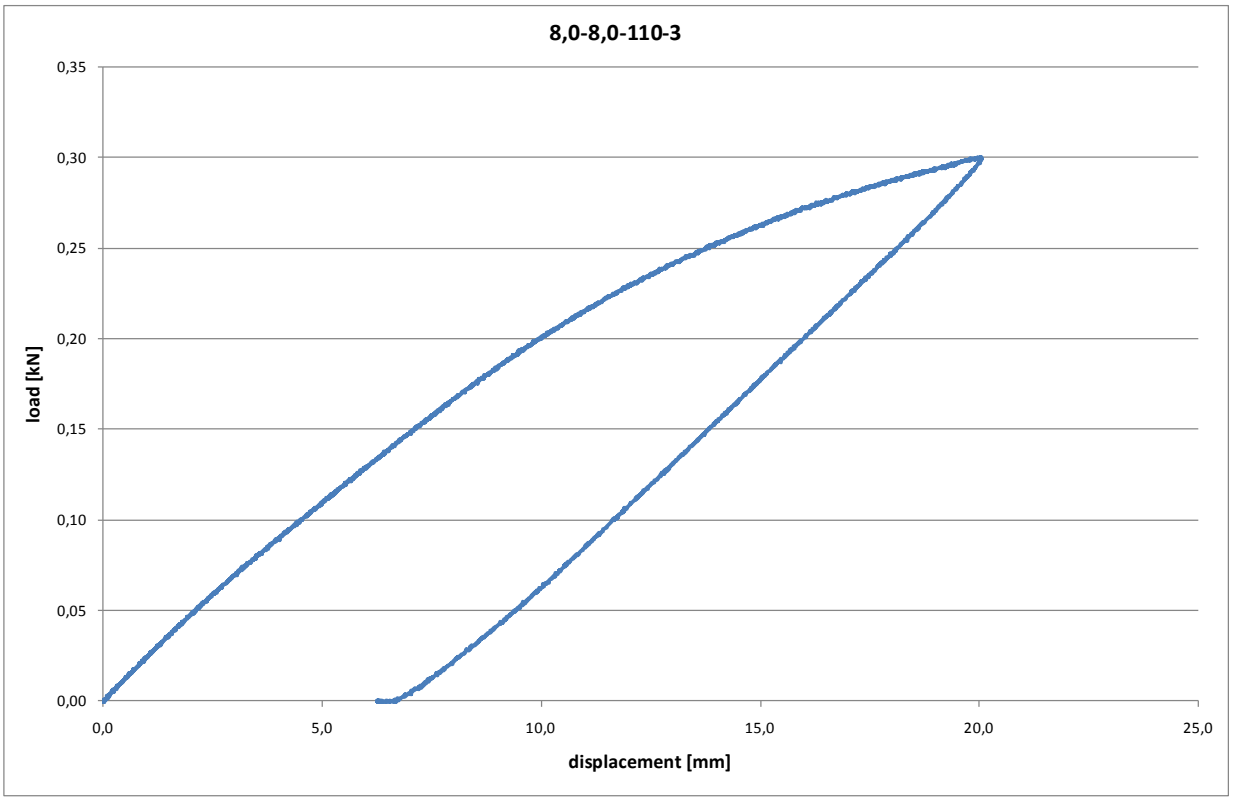
Thickness of substructure: 8,0 mm

Nominal diameter of fastener: 8,0 mm

Lever arm: 110 mm




8,0-8,0-110-2
load [kN]
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
displacement [mm]


8,0-8,0-110-3
load [kN]
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
0,0
5,0
10,0
15,0
20,0
25,0
displacement [mm]

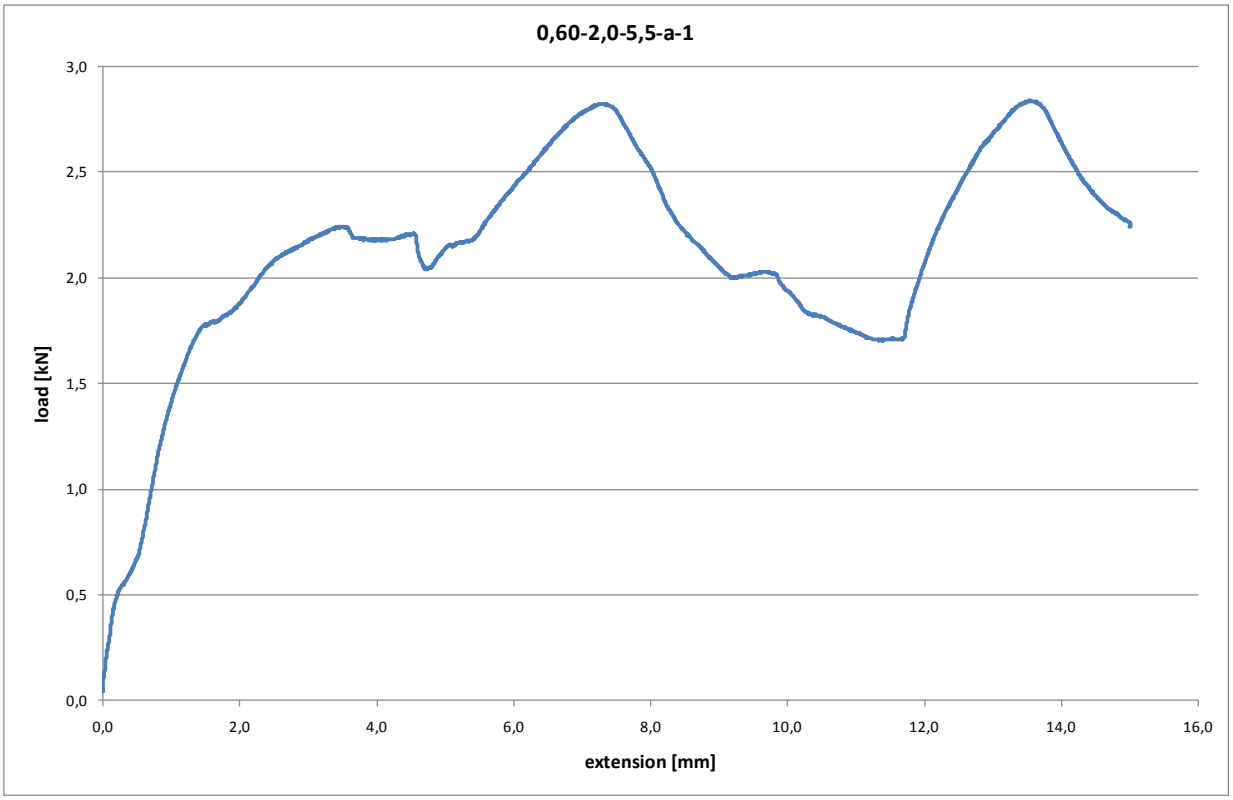
Tests on clamping of the head:

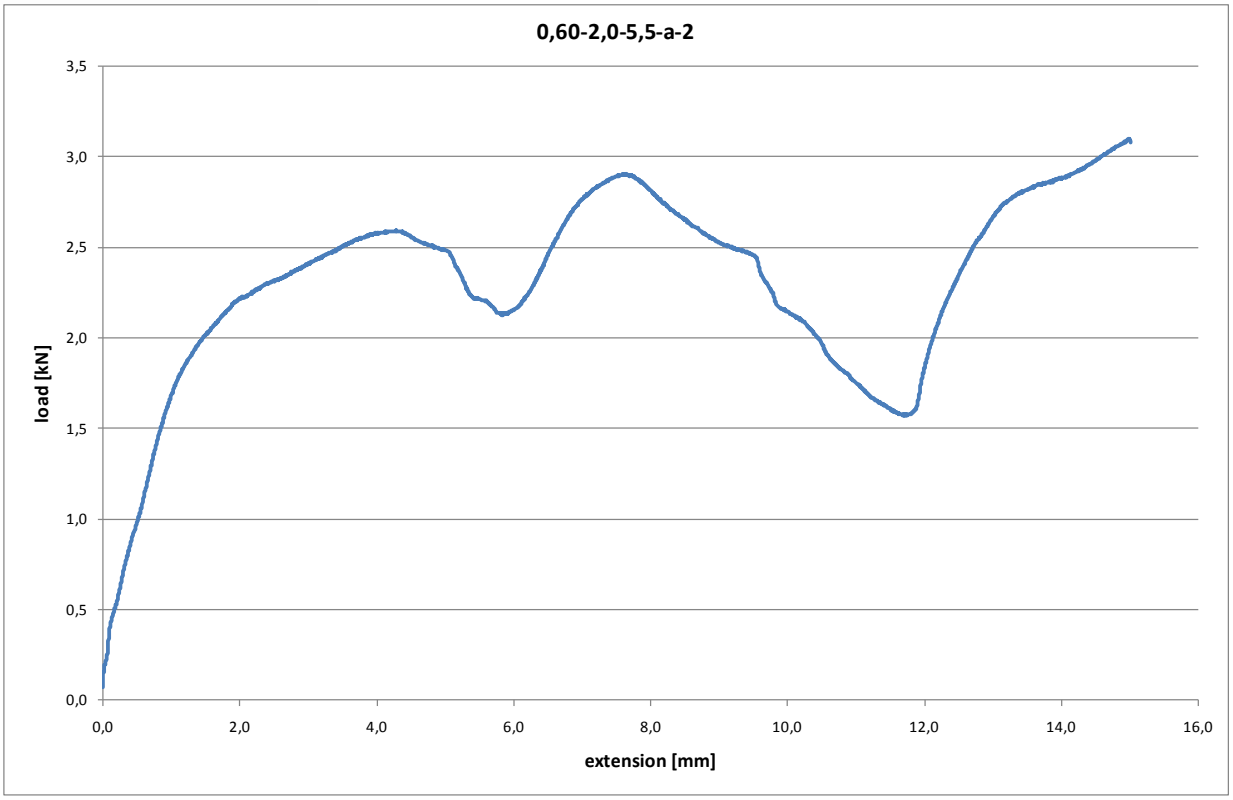
Thickness of face sheet: 0,60 mm

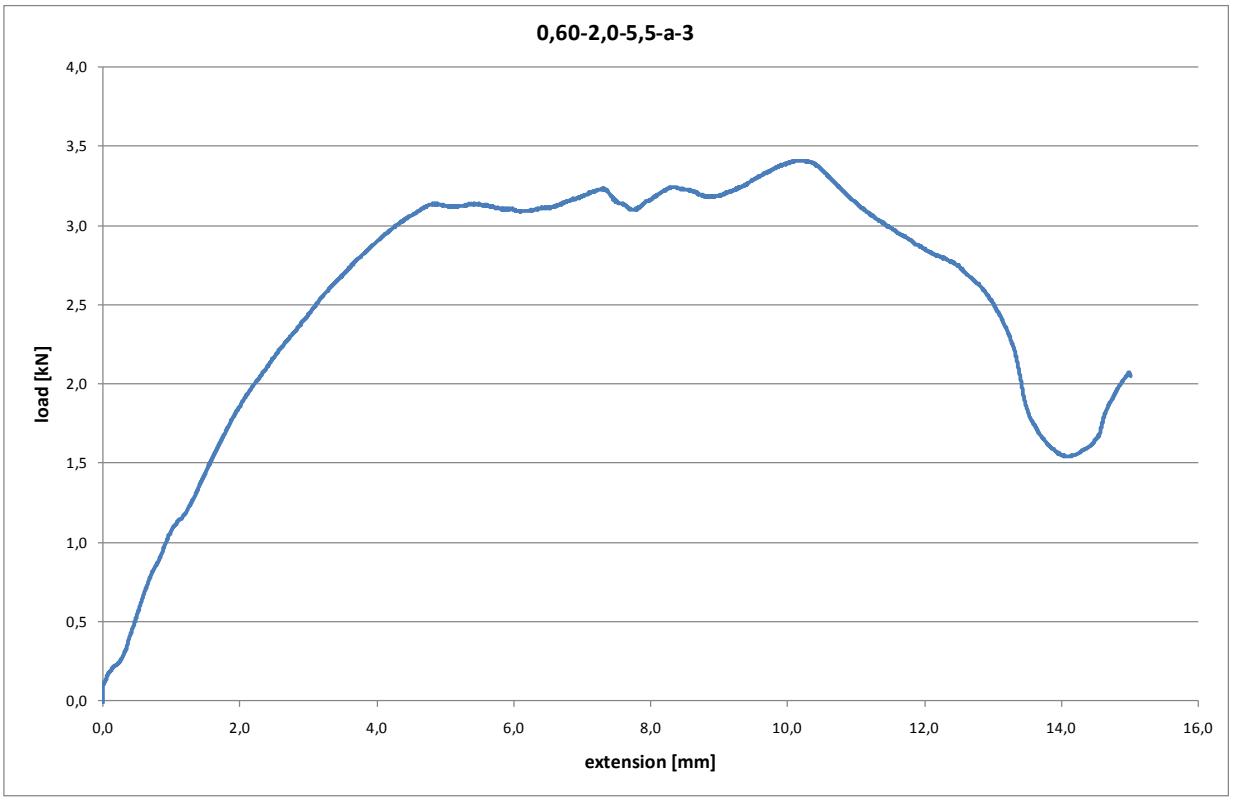
Thickness of substructure: 2,0 mm

Nominal diameter of the fastener: 5,5 mm

With clamping of the head




0,60-2,0-5,5-a-2
load [kN]
extension [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0


0,60-2,0-5,5-a-3
load [kN]
extension [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0

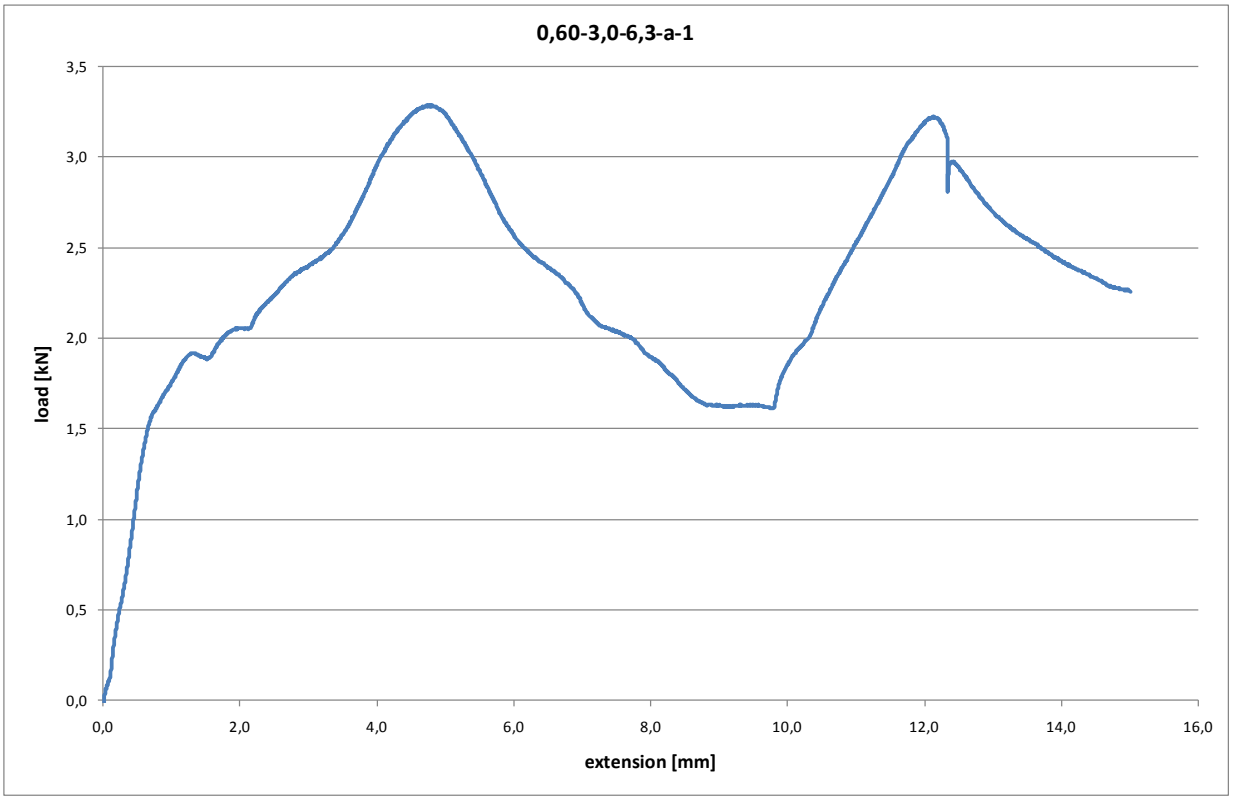
Tests on clamping of the head:

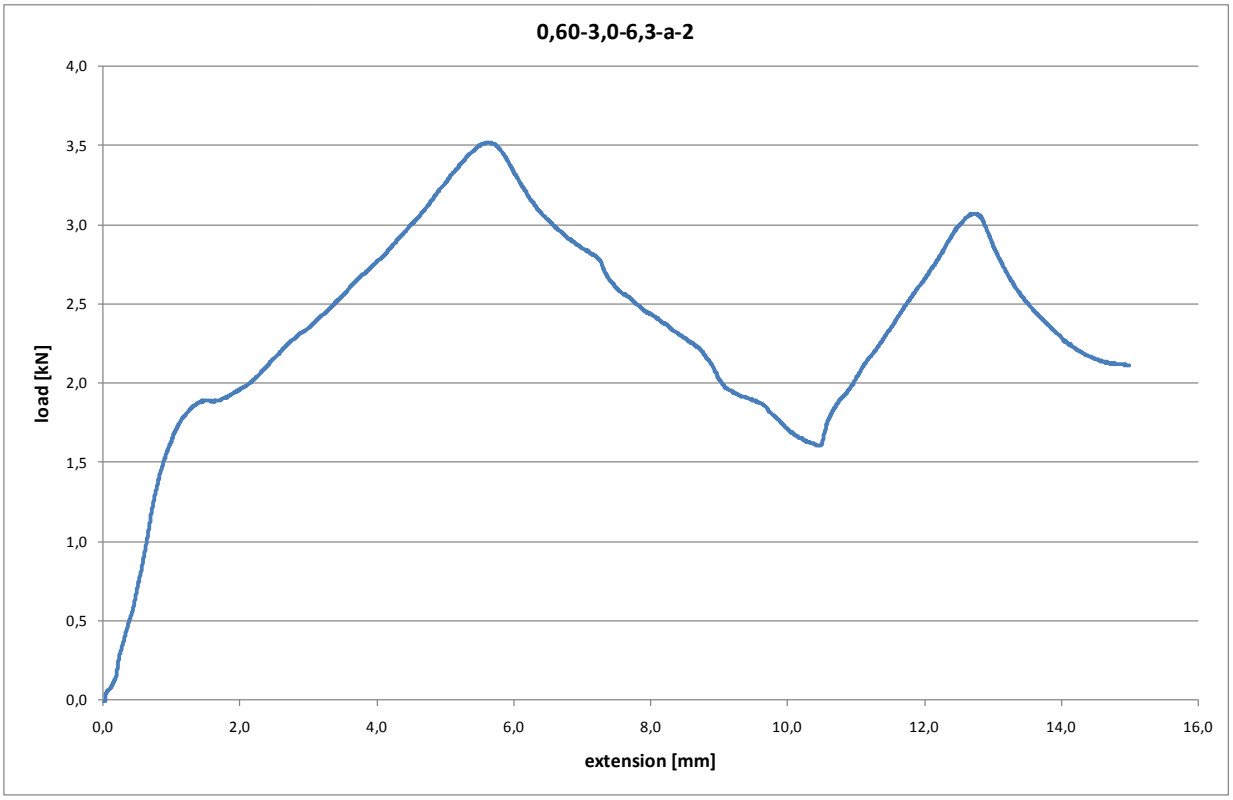
Thickness of face sheet: 0,60 mm

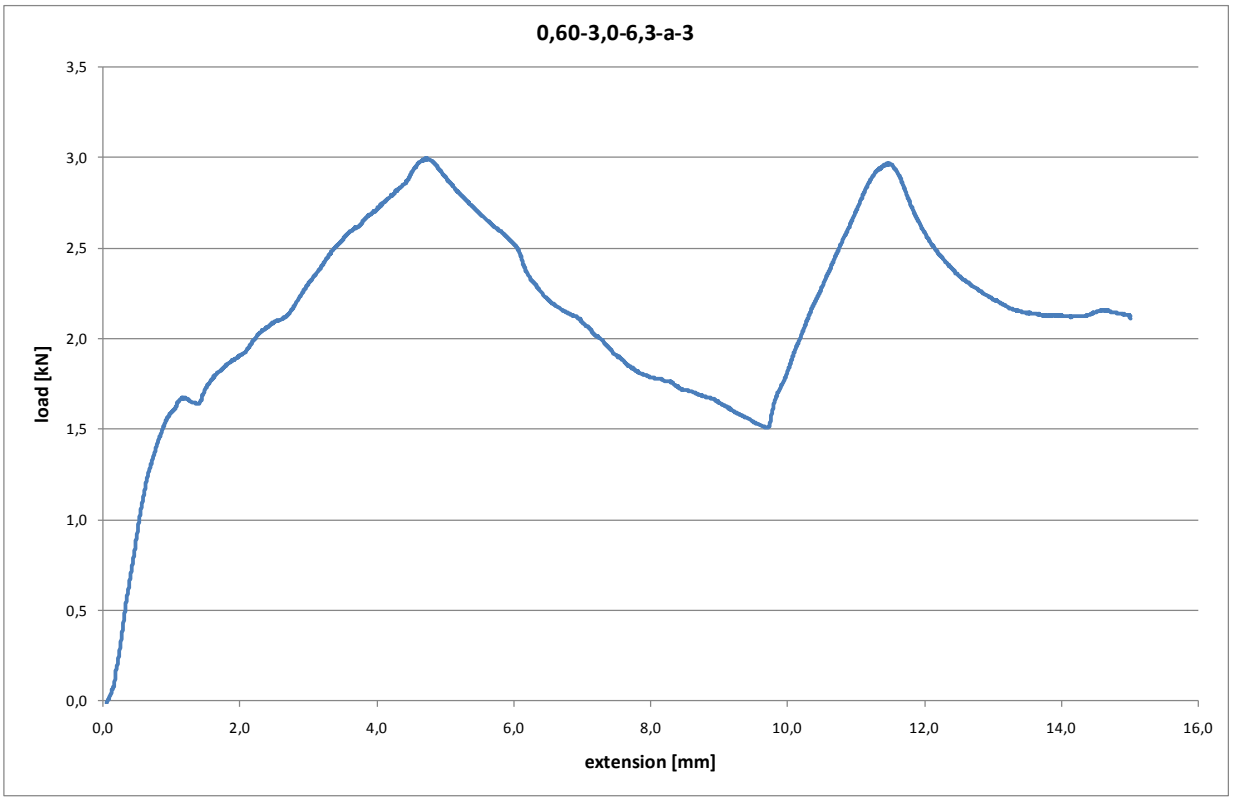
Thickness of substructure: 3,0 mm

Nominal diameter of the fastener: 6,3 mm

With clamping of the head




0,60-3,0-6,3-a-2
load [kN]
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
extension [mm]


0,60-3,0-6,3-a-3
load [kN]
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
extension [mm]

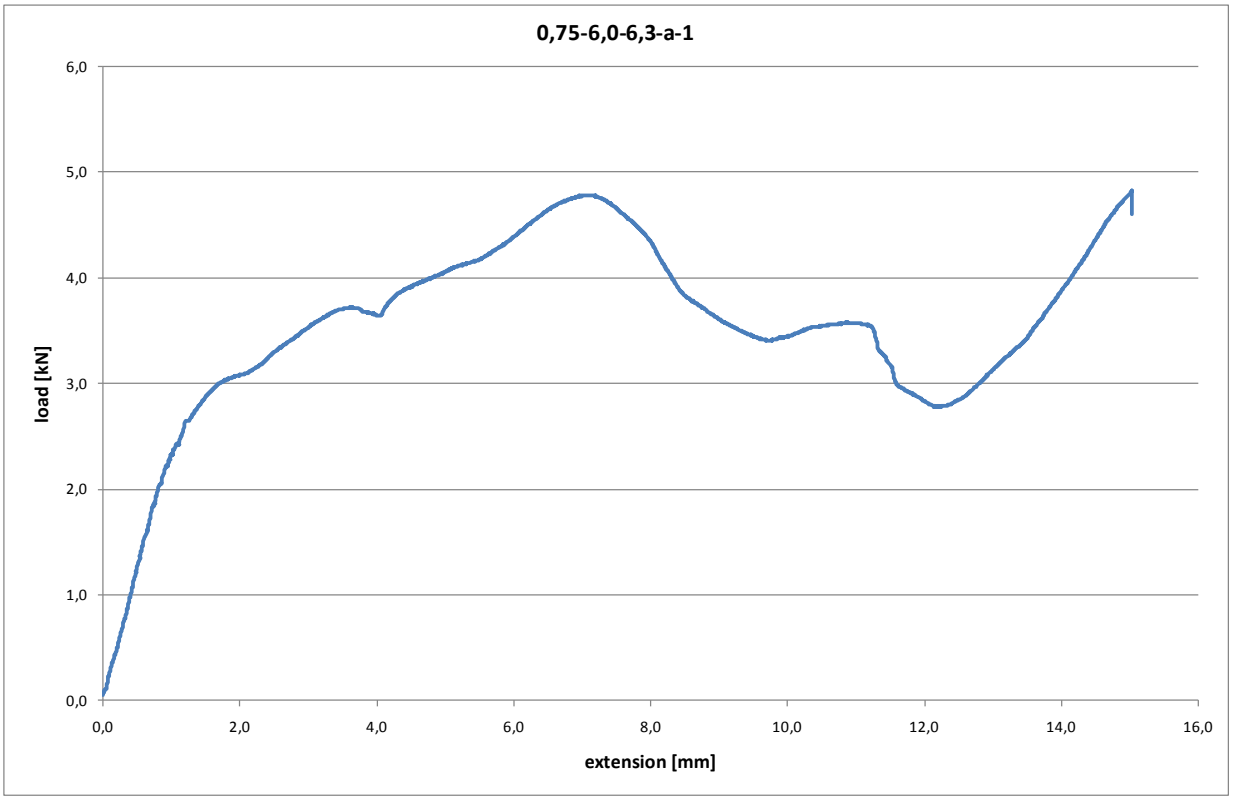
Tests on clamping of the head:

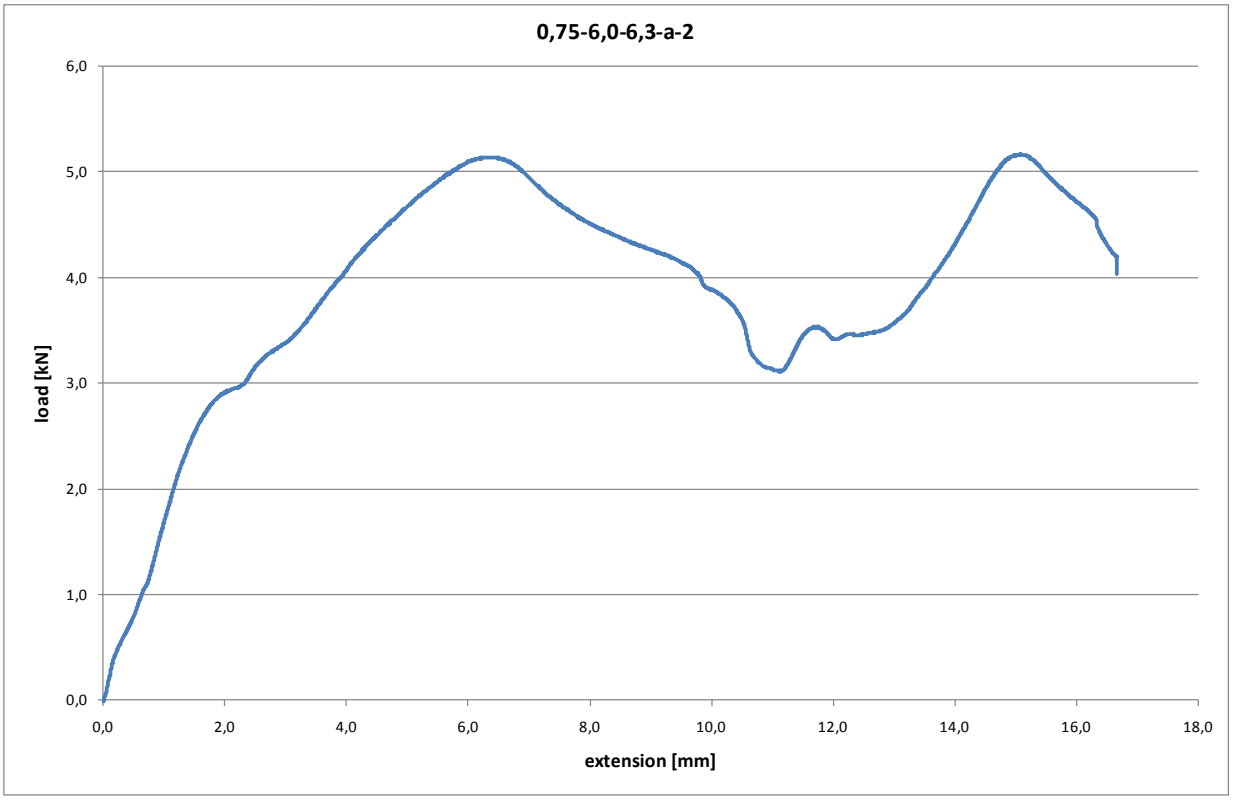
Thickness of face sheet: 0,75 mm

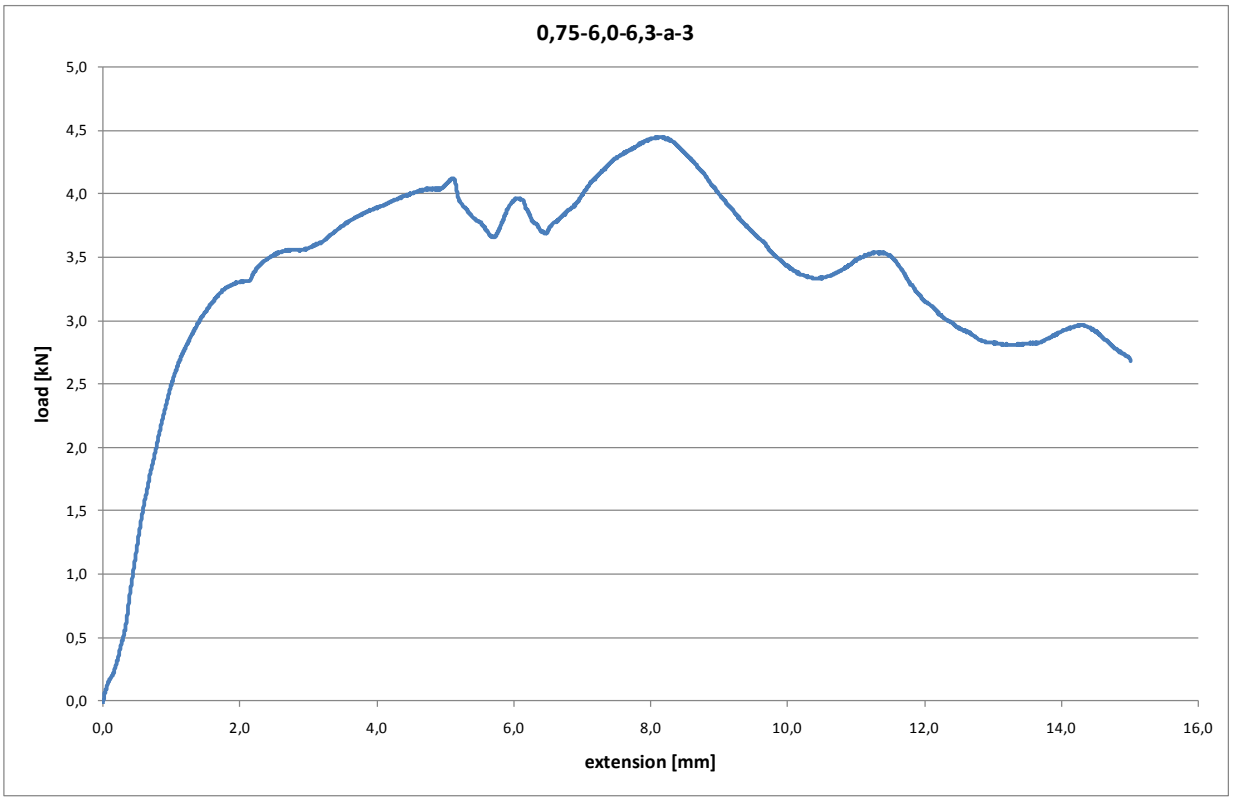
Thickness of substructure: 6,0 mm

Nominal diameter of the fastener: 6,3 mm

With clamping of the head




0,75-6,0-6,3-a-2
load [kN]
6,0
5,0
4,0
3,0
2,0
1,0
0,0
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
18,0
extension [mm]


0,75-6,0-6,3-a-3
load [kN]
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
extension [mm]

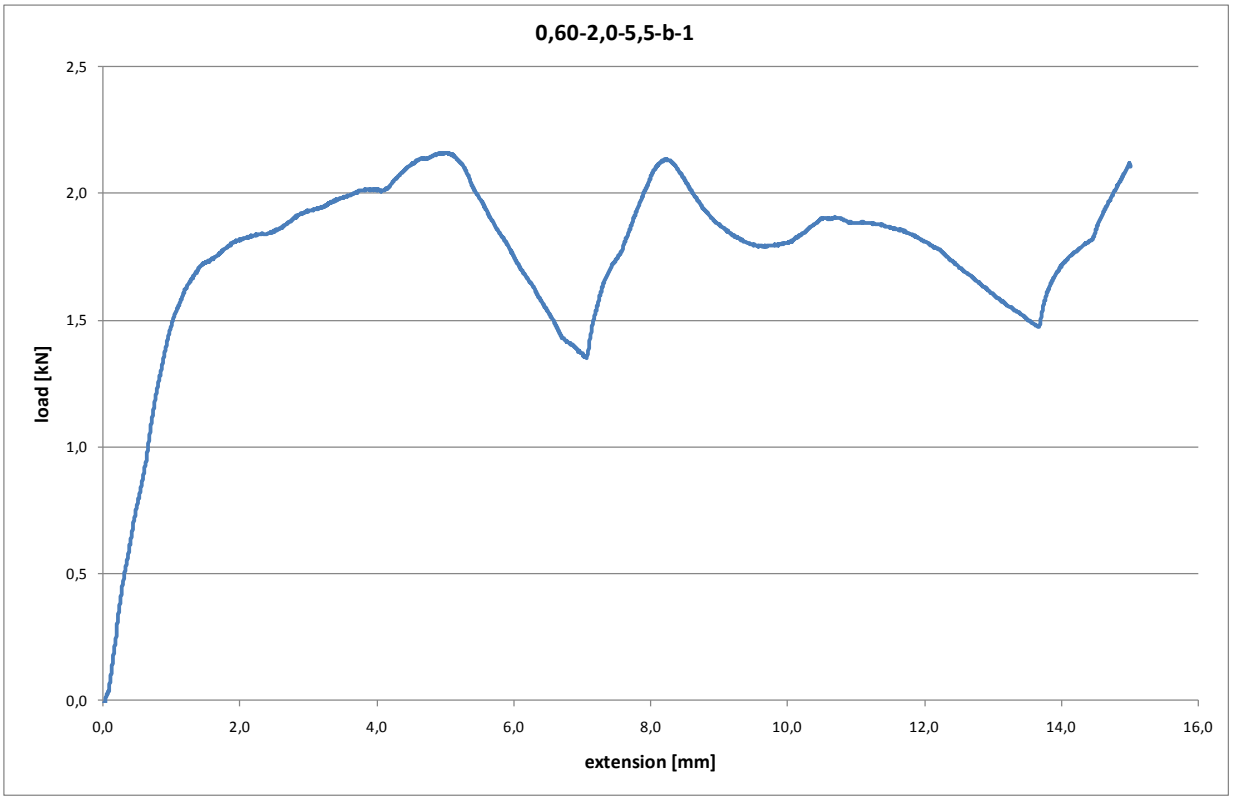
Tests on clamping of the head:

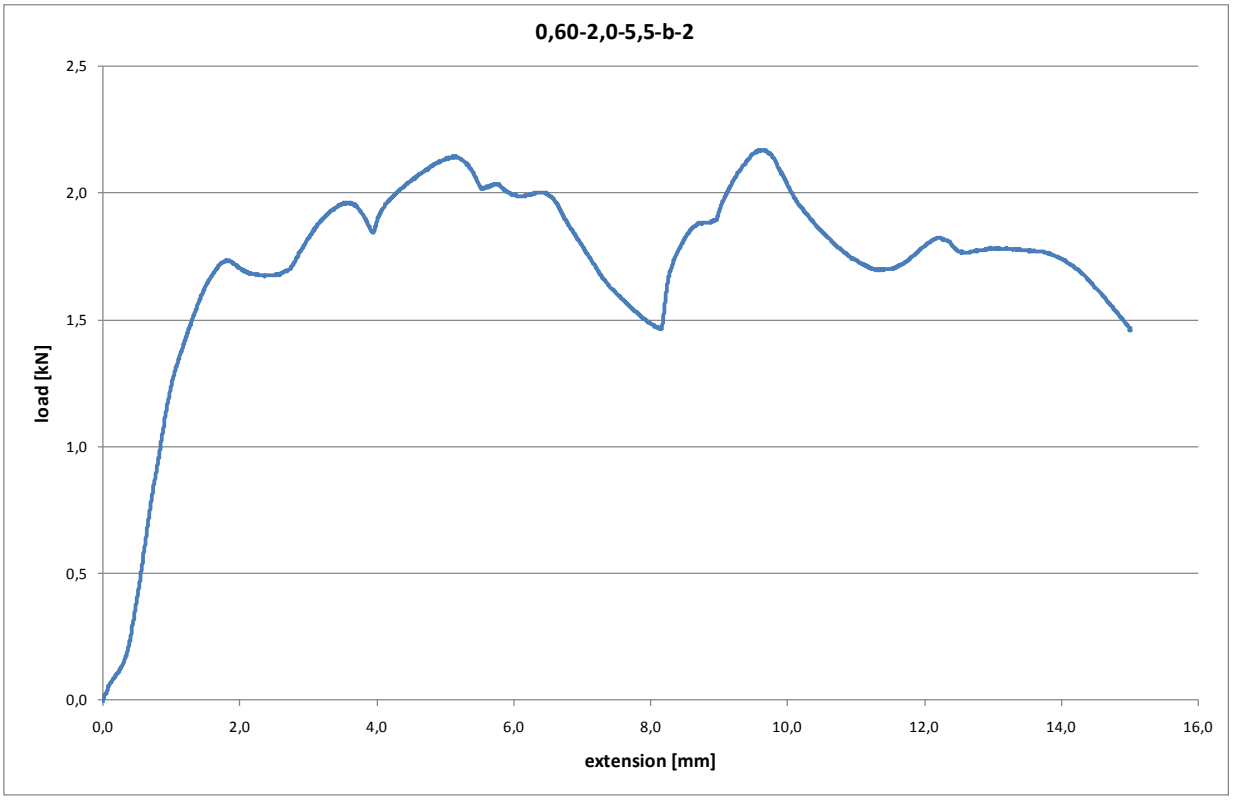
Thickness of face sheet: 0,60 mm

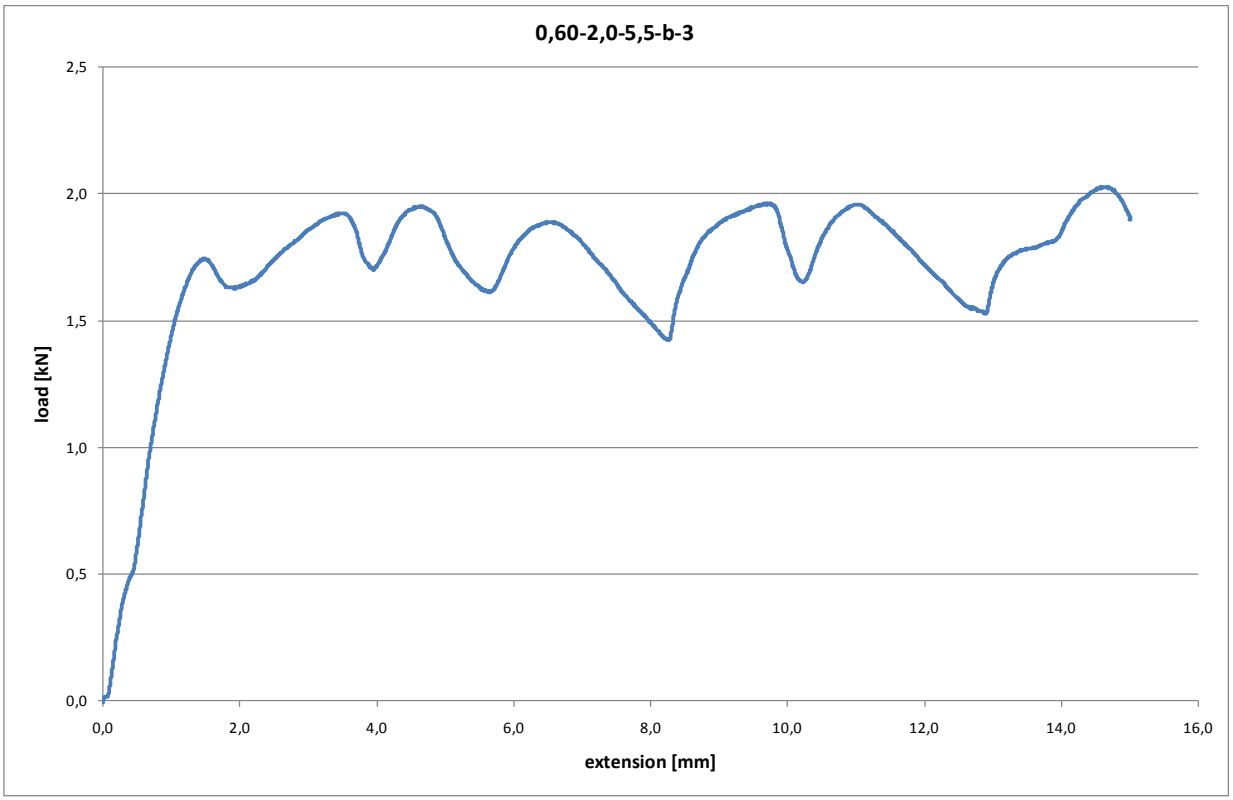
Thickness of substructure: 2,0 mm

Nominal diameter of the fastener: 5,5 mm

Without clamping of the head




0,60-2,0-5,5-b-2
load [kN]
2,5
2,0
1,5
1,0
0,5
0,0
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
extension [mm]


0,60-2,0-5,5-b-3
load [kN]
2,5
2,0
1,5
1,0
0,5
0,0
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
extension [mm]

-

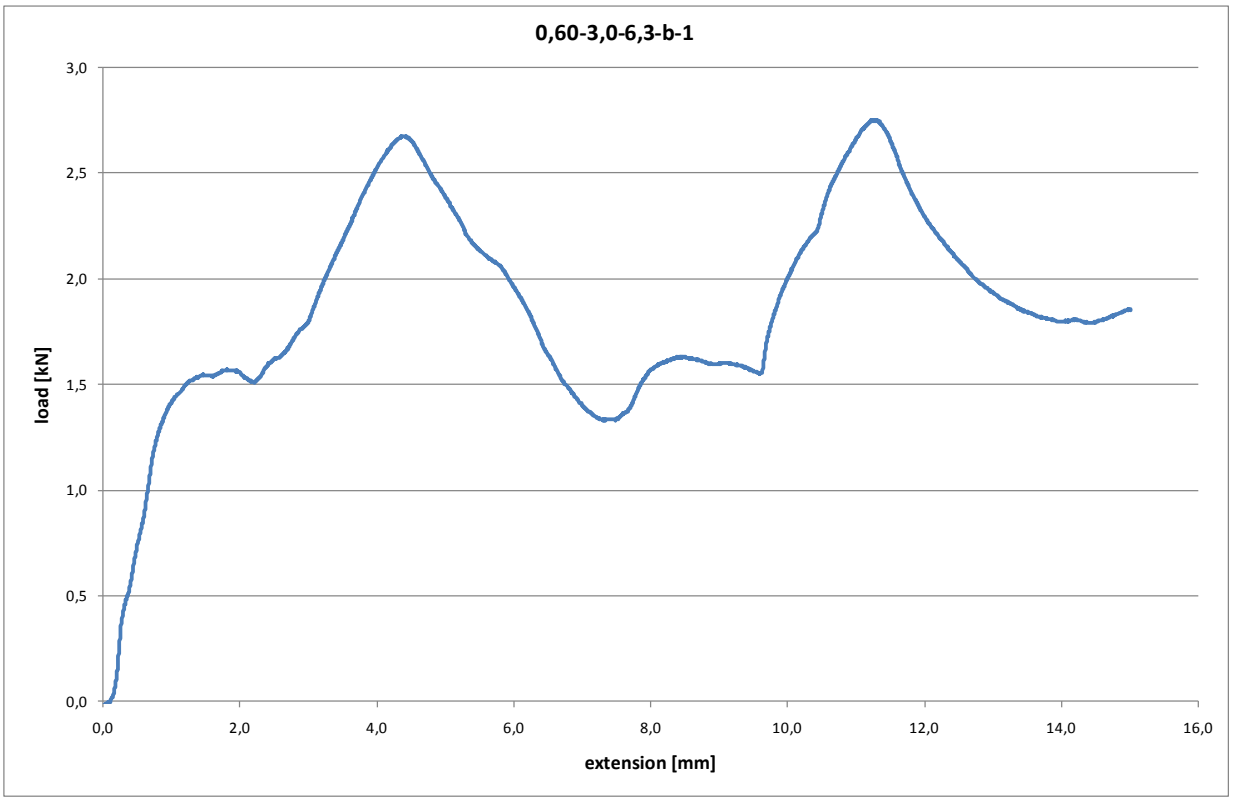
Tests on clamping of the head:

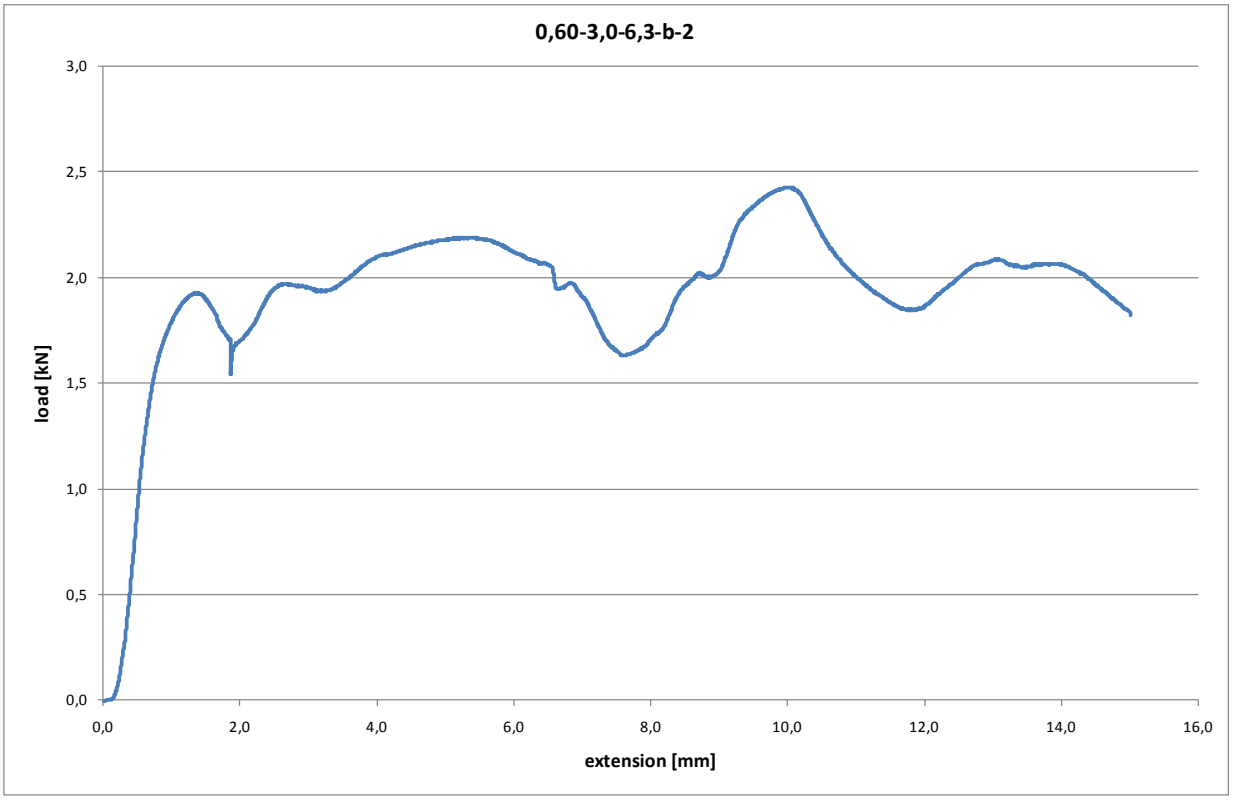
Thickness of face sheet: 0,60 mm

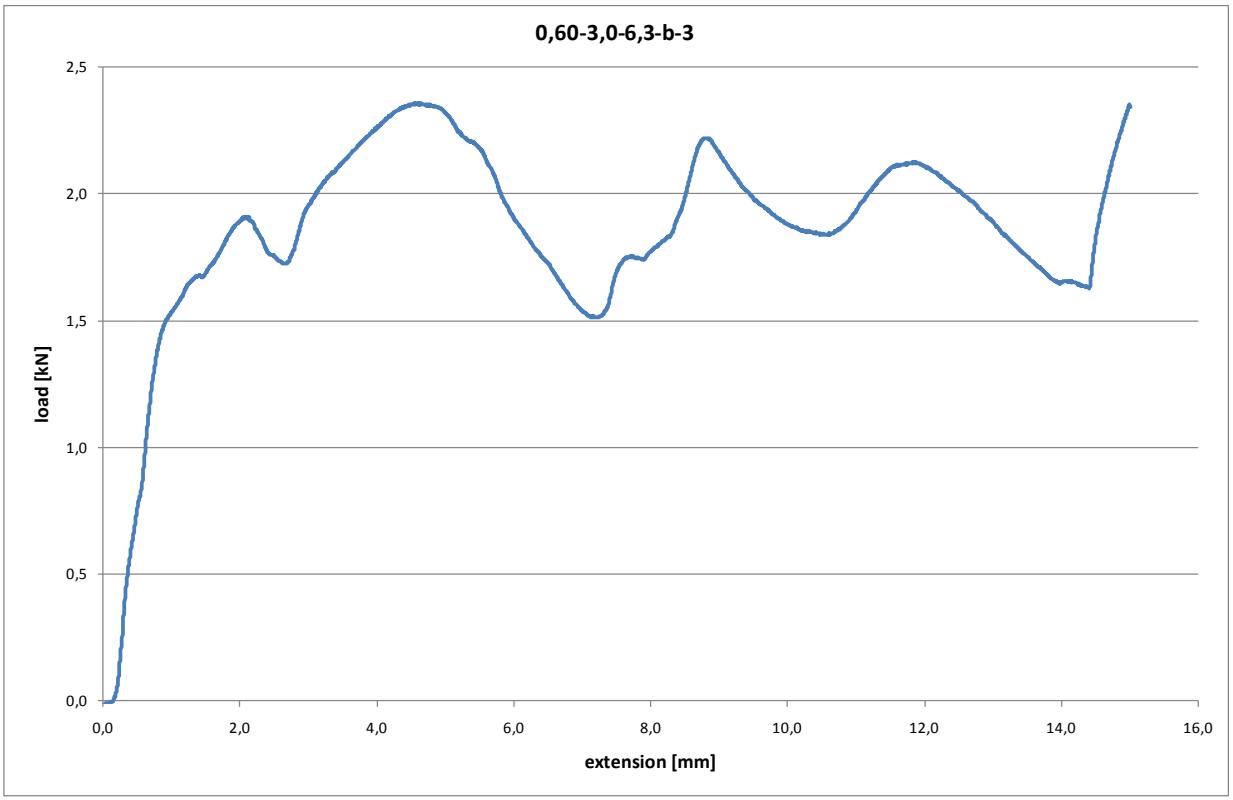
Thickness of substructure: 3,0 mm

Nominal diameter of the fastener: 6,3 mm

Without clamping of the head




0,60-3,0-6,3-b-2
load [kN]
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
extension [mm]


0,60-3,0-6,3-b-3
load [kN]
2,5
2,0
1,5
1,0
0,5
0,0
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
extension [mm]

-

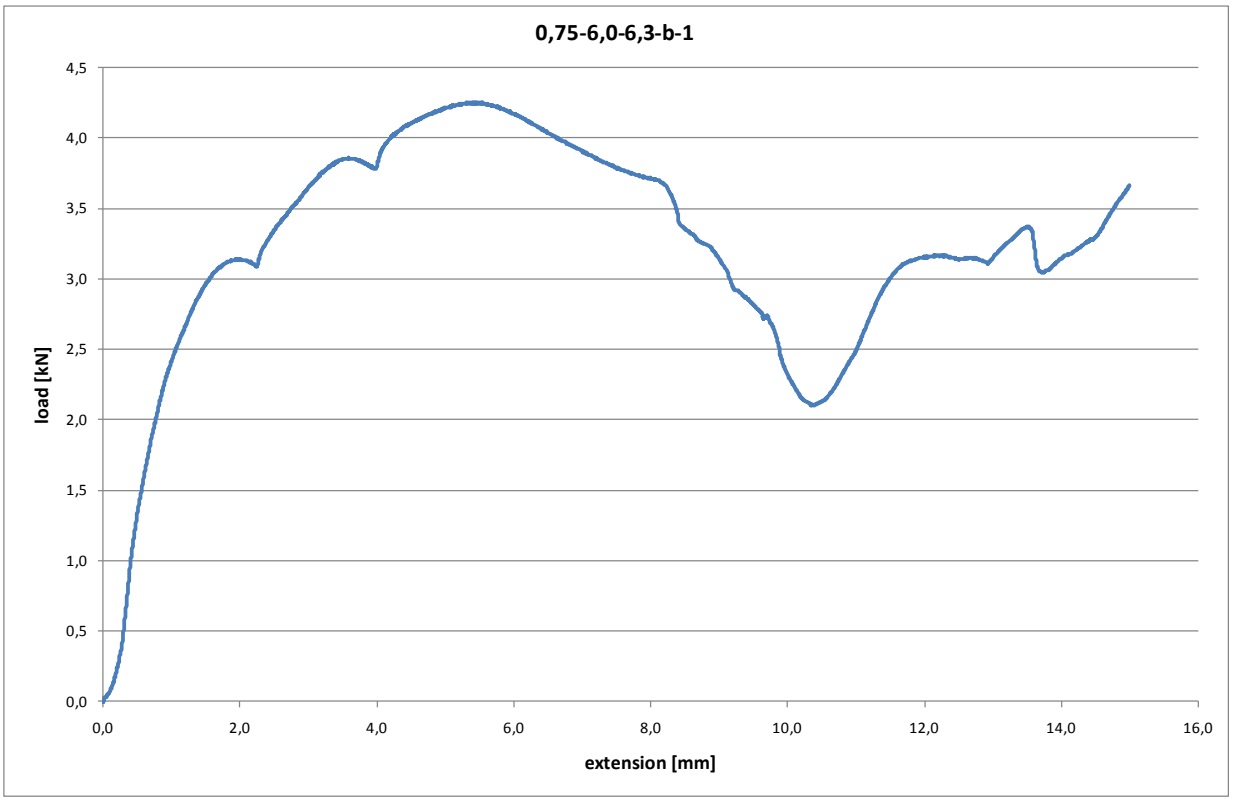
Tests on clamping of the head:

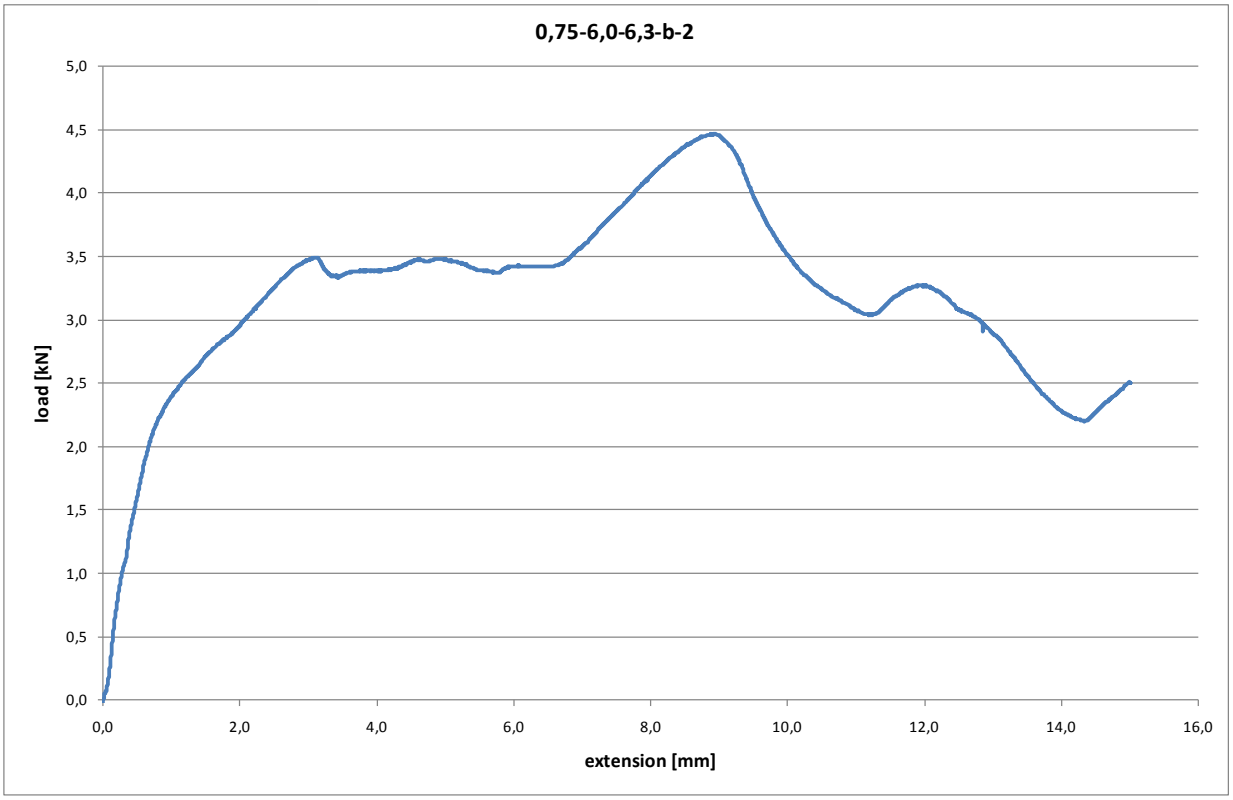
Thickness of face sheet: 0,75 mm

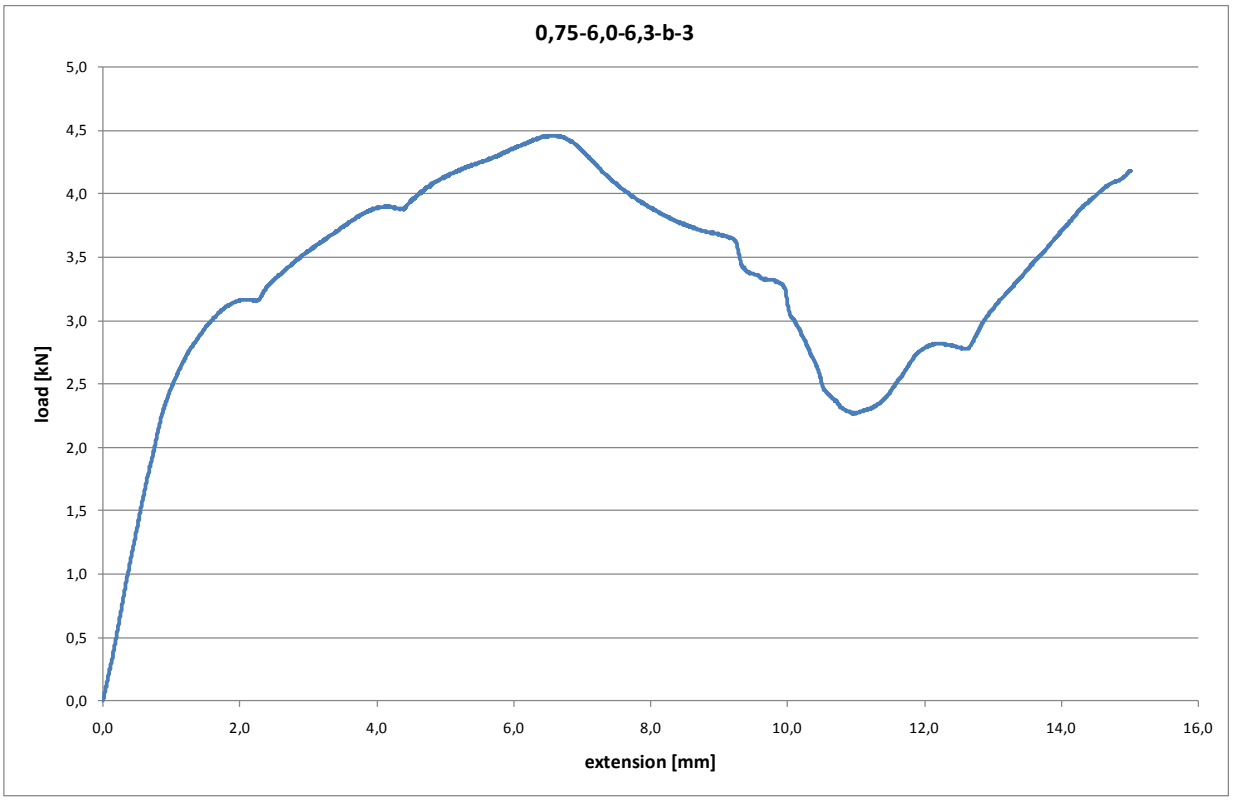
Thickness of substructure: 6,0 mm

Nominal diameter of the fastener: 6,3 mm

Without clamping of the head




0,75-6,0-6,3-b-2
load [kN]
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
extension [mm]

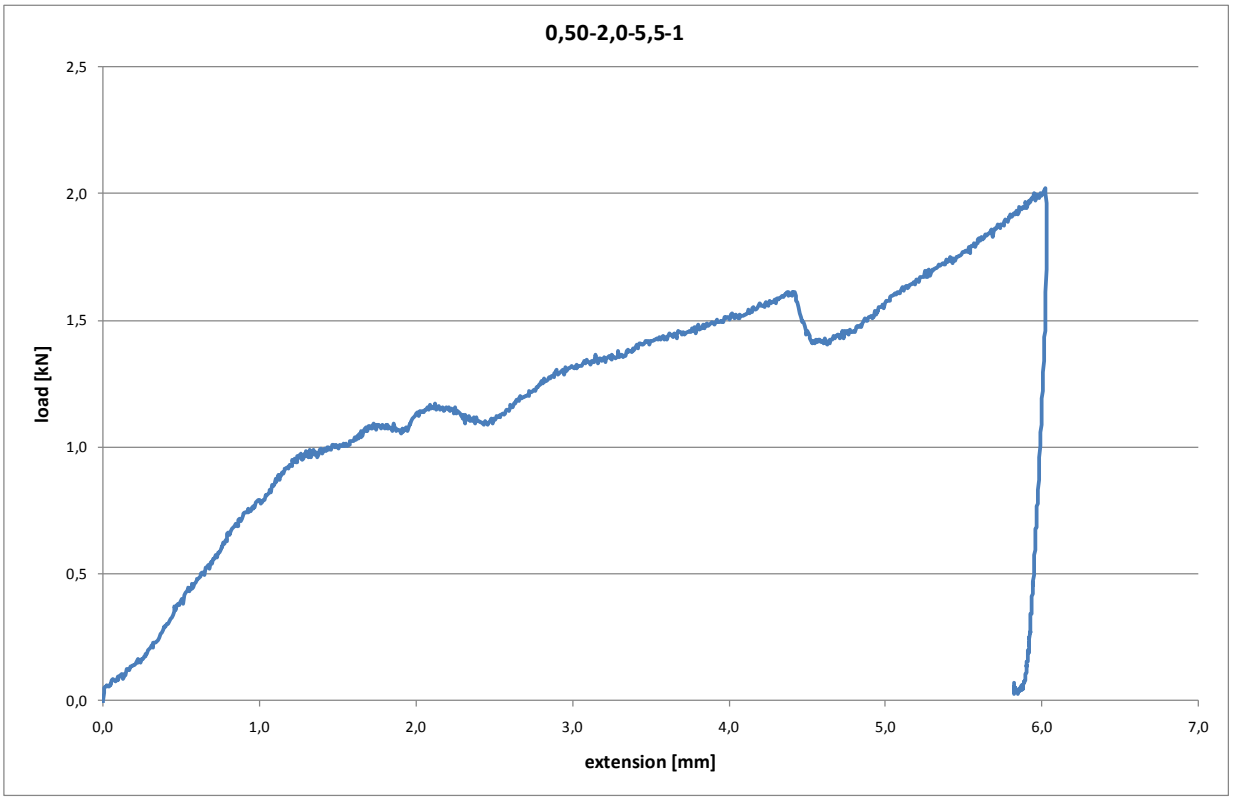

0,75-6,0-6,3-b-3
load [kN]
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
extension [mm]

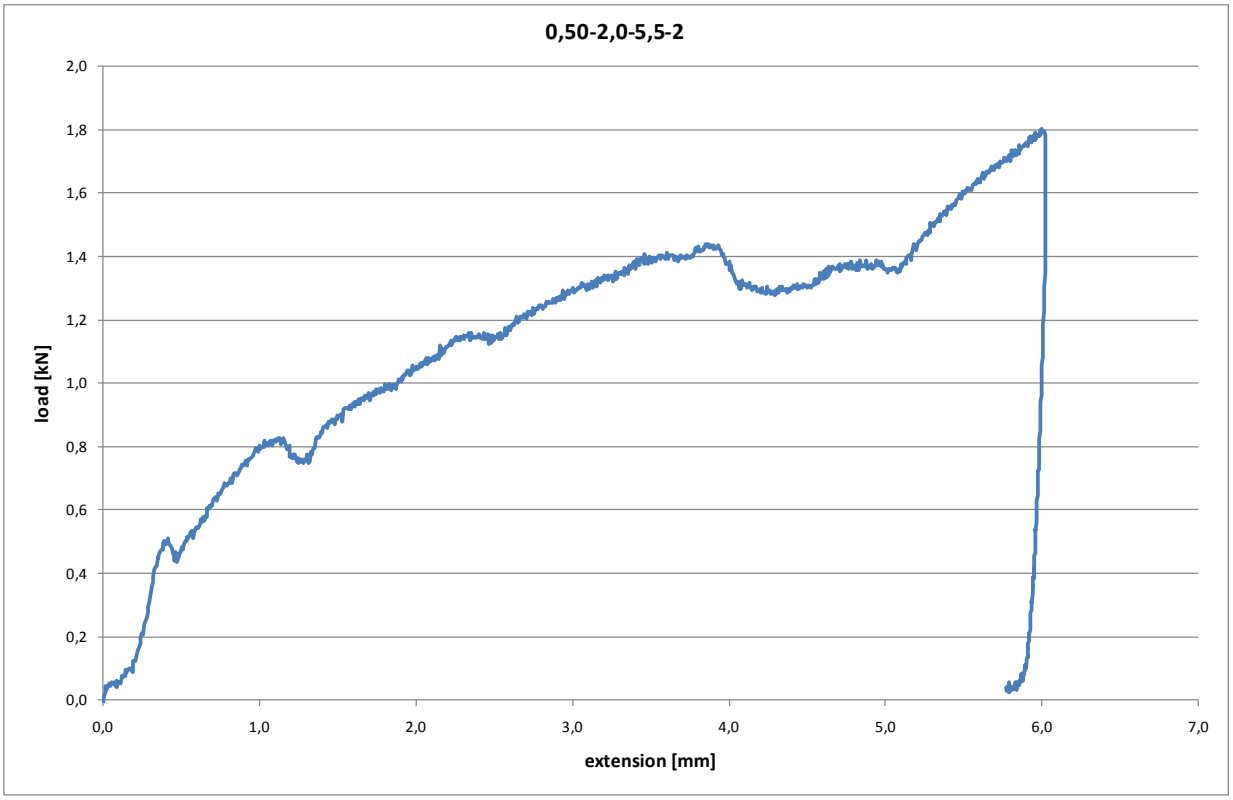
Full-scale tests

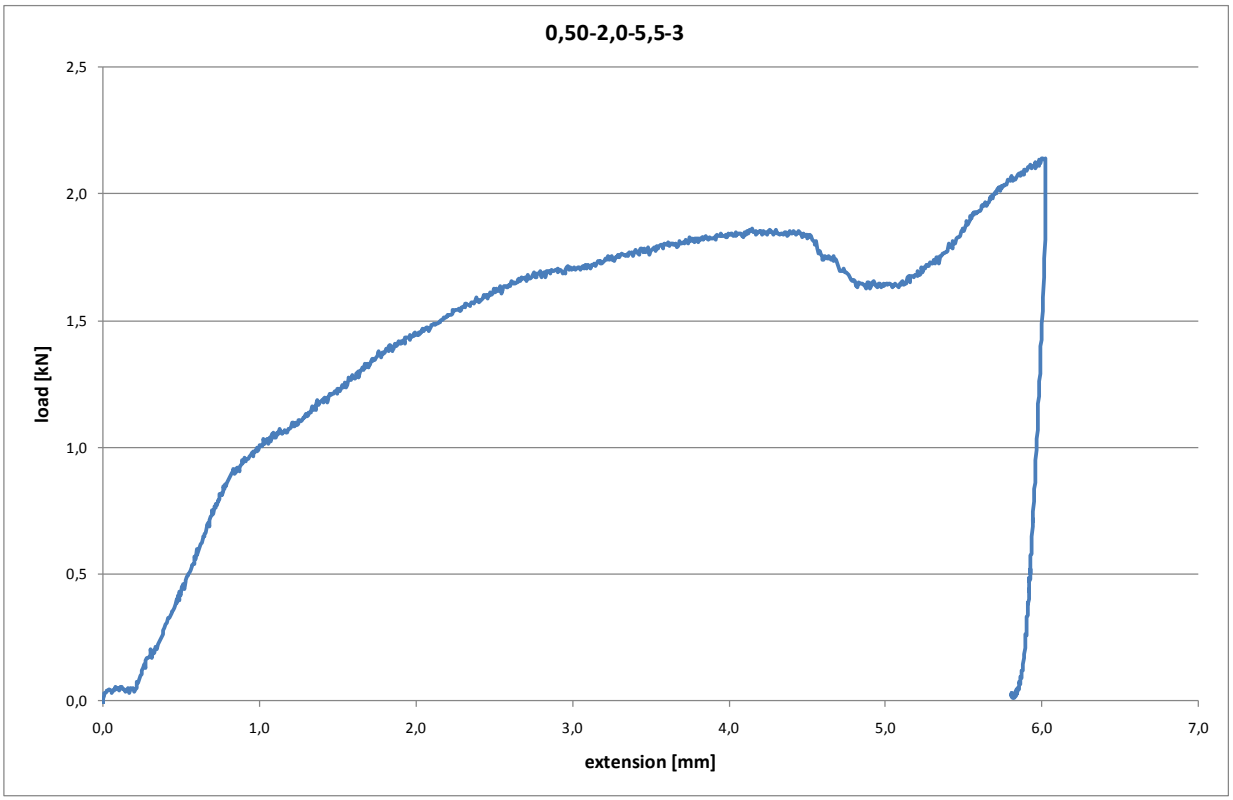
Thickness of face sheet: 0,50 mm

Thickness of substructure: 2,0 mm

Nominal diameter of fastener: 5,5 mm




0,50-2,0-5,5-2
load [kN]
extension [mm]
2,0
1,8
1,6
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

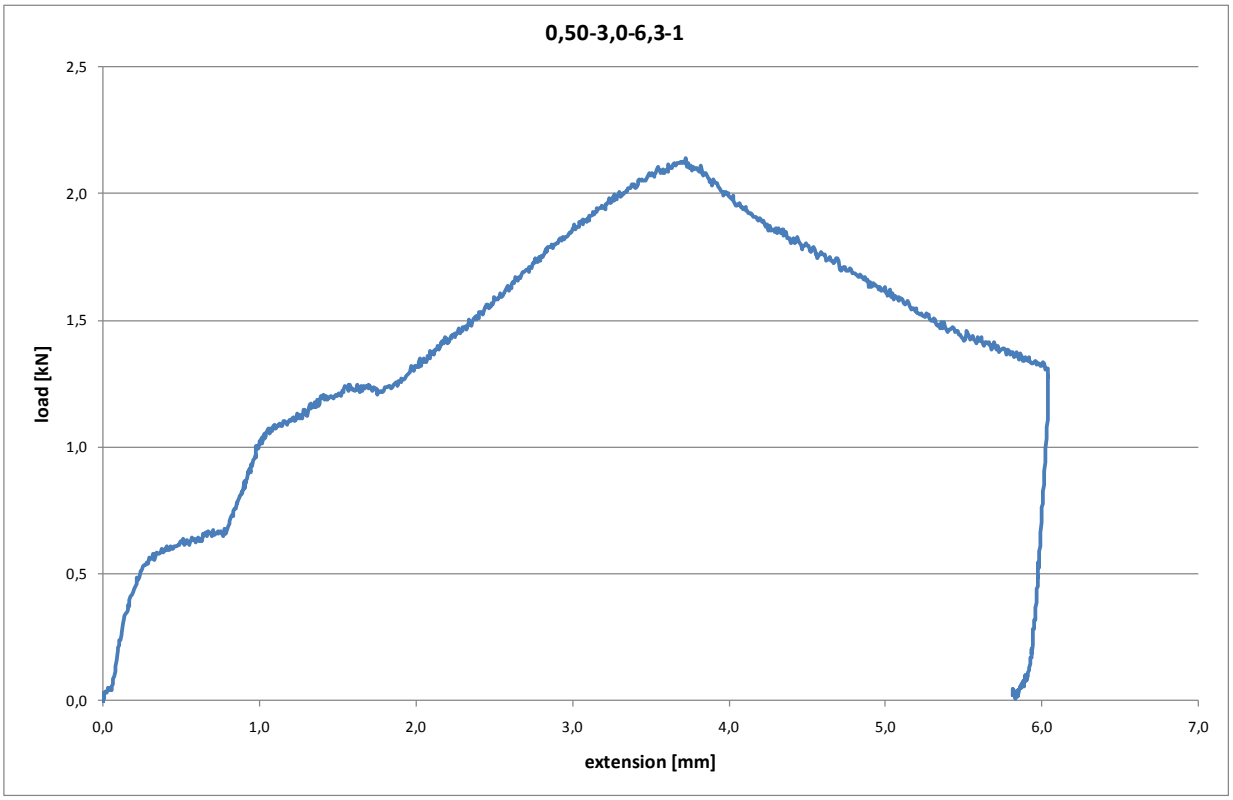

0,50-2,0-5,5-3
load [kN]
extension [mm]
2,5
2,0
1,5
1,0
0,5
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

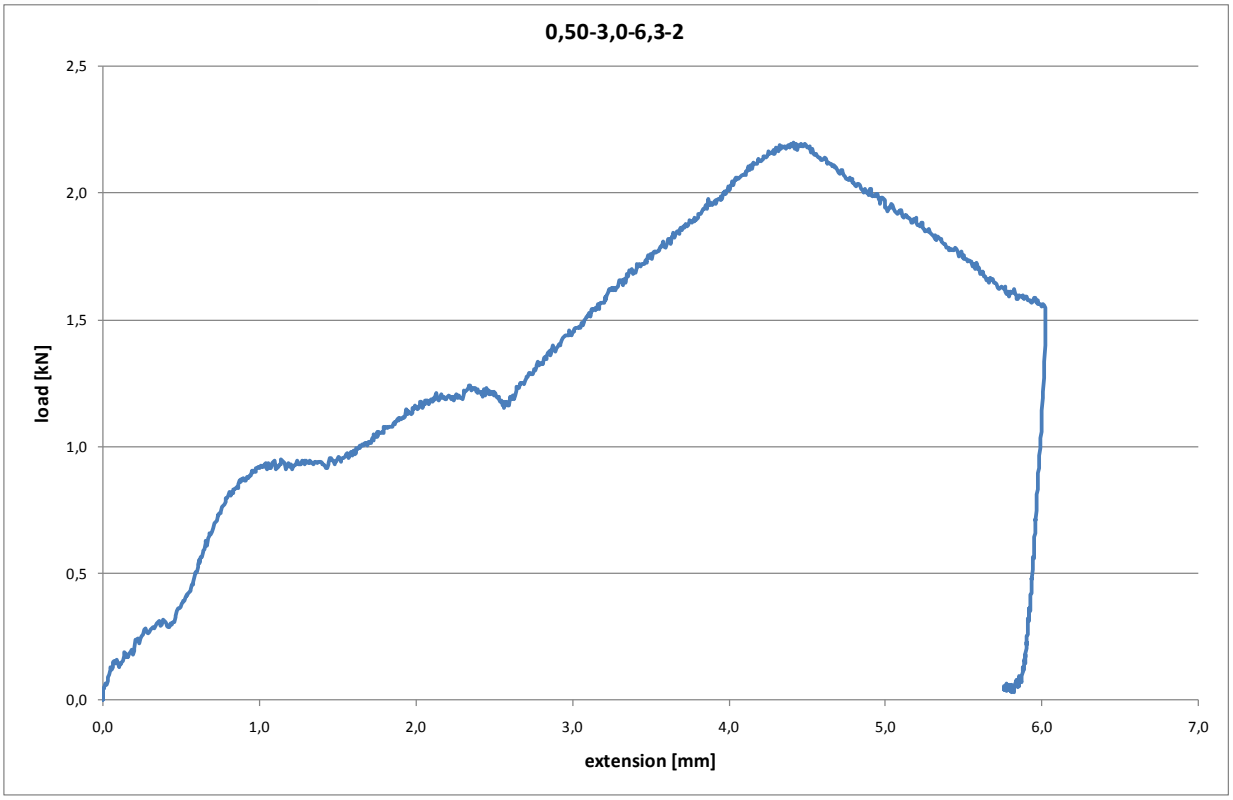
Full-scale tests

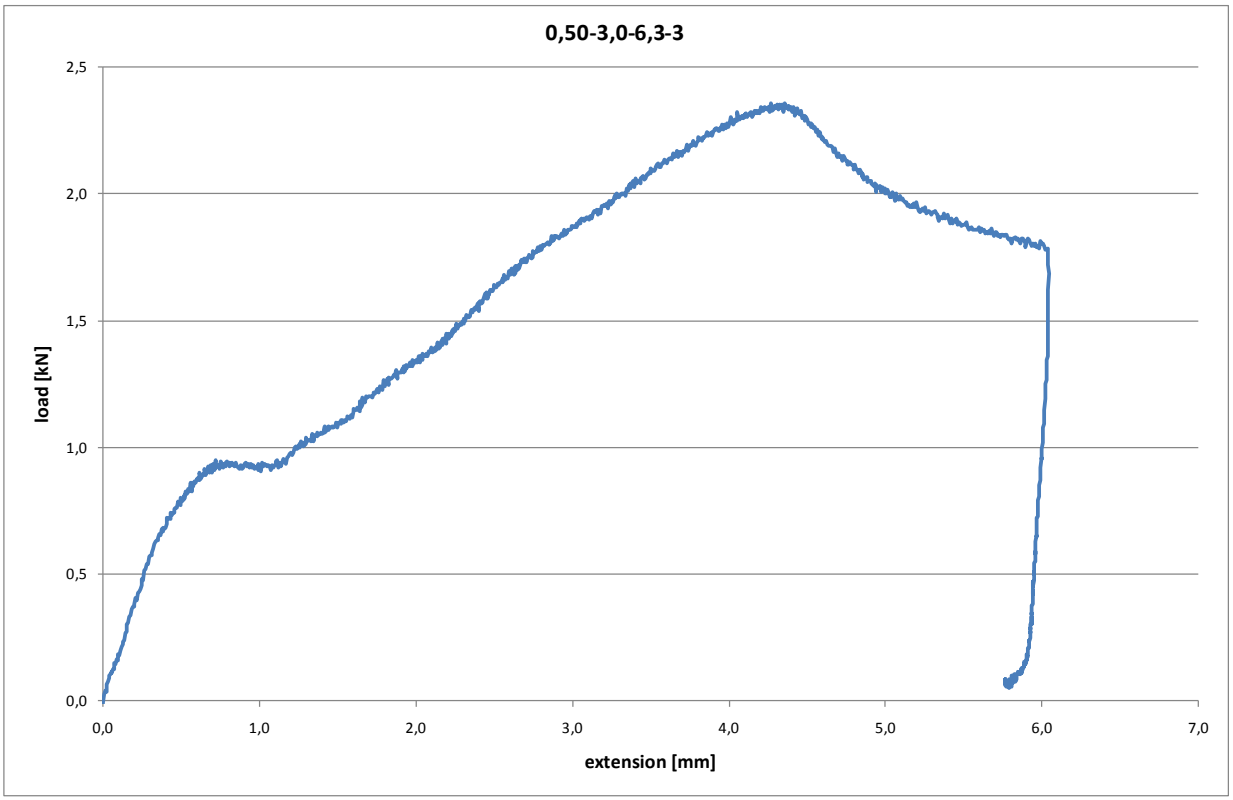
Thickness of face sheet: 0,50 mm

Thickness of substructure: 3,0 mm

Nominal diameter of fastener: 6,3 mm




0,50-3,0-6,3-2
load [kN]
extension [mm]
2,5
2,0
1,5
1,0
0,5
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

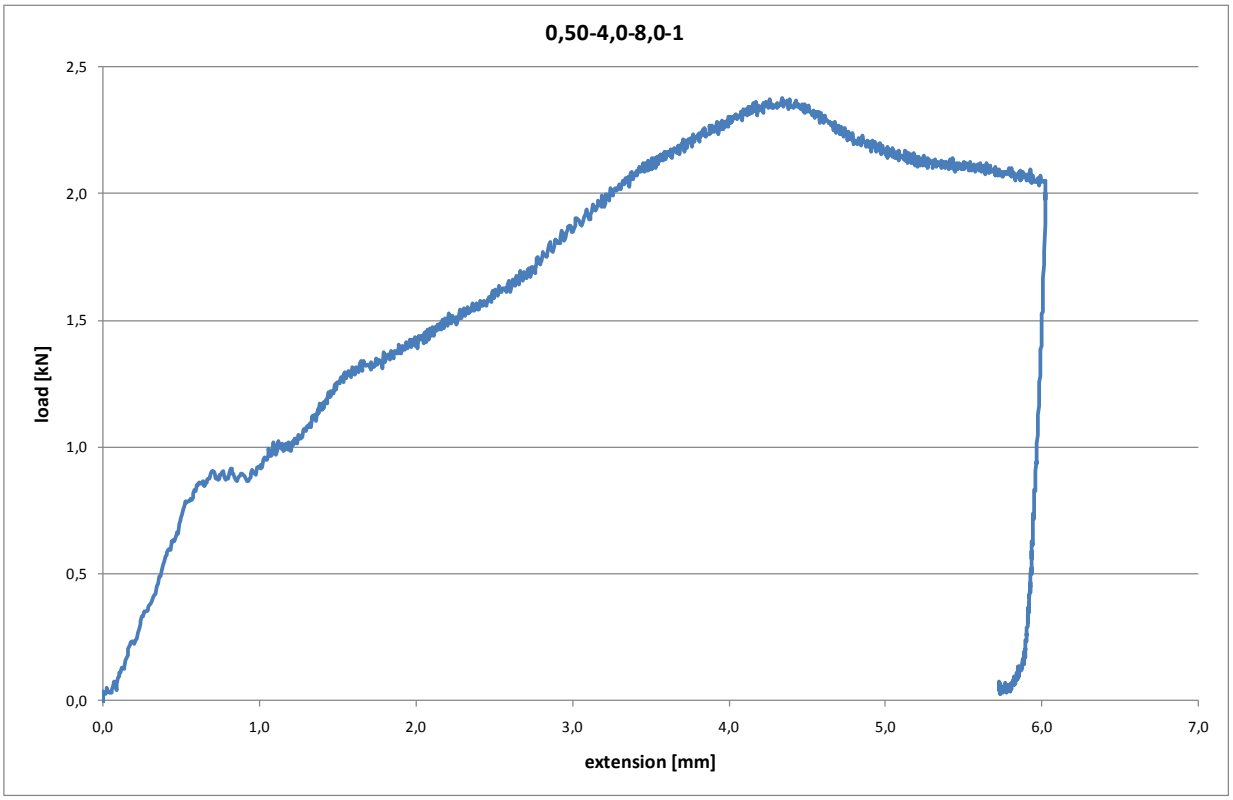

0,50-3,0-6,3-3
load [kN]
extension [mm]
2,5
2,0
1,5
1,0
0,5
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

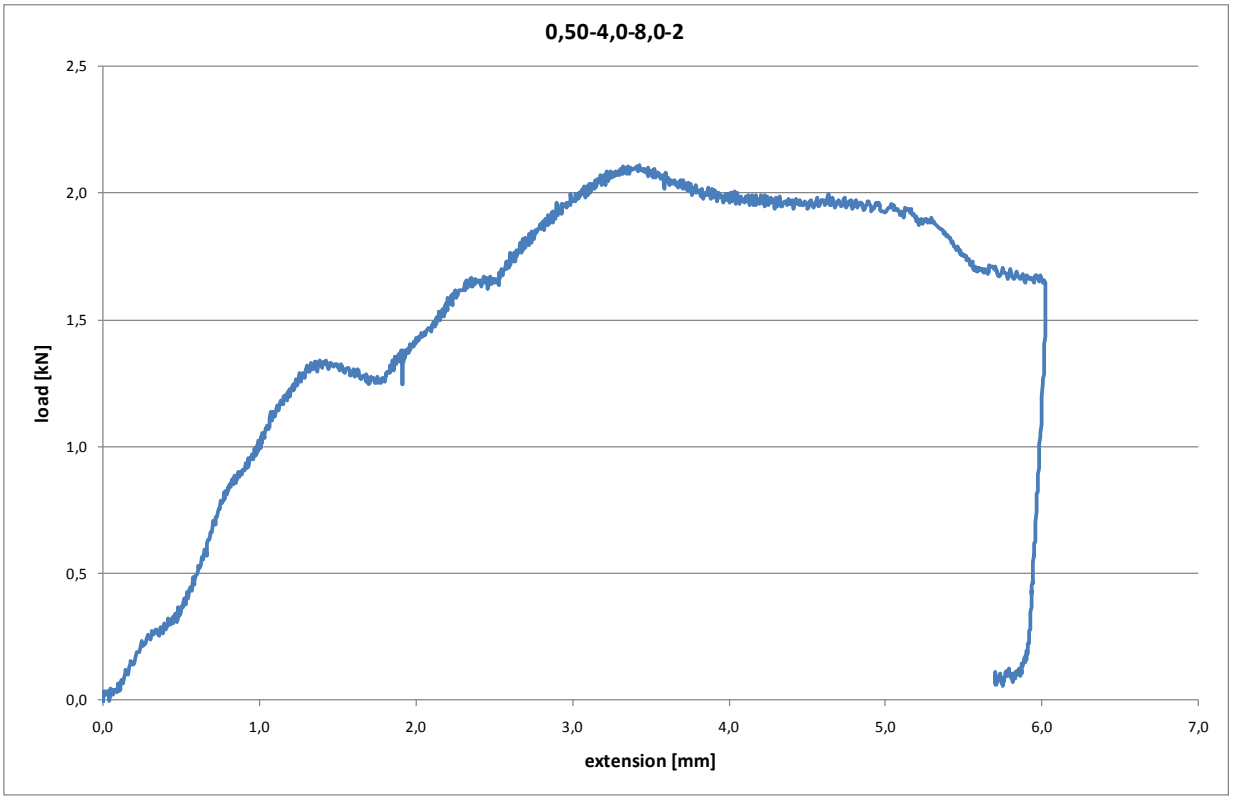
Full-scale tests

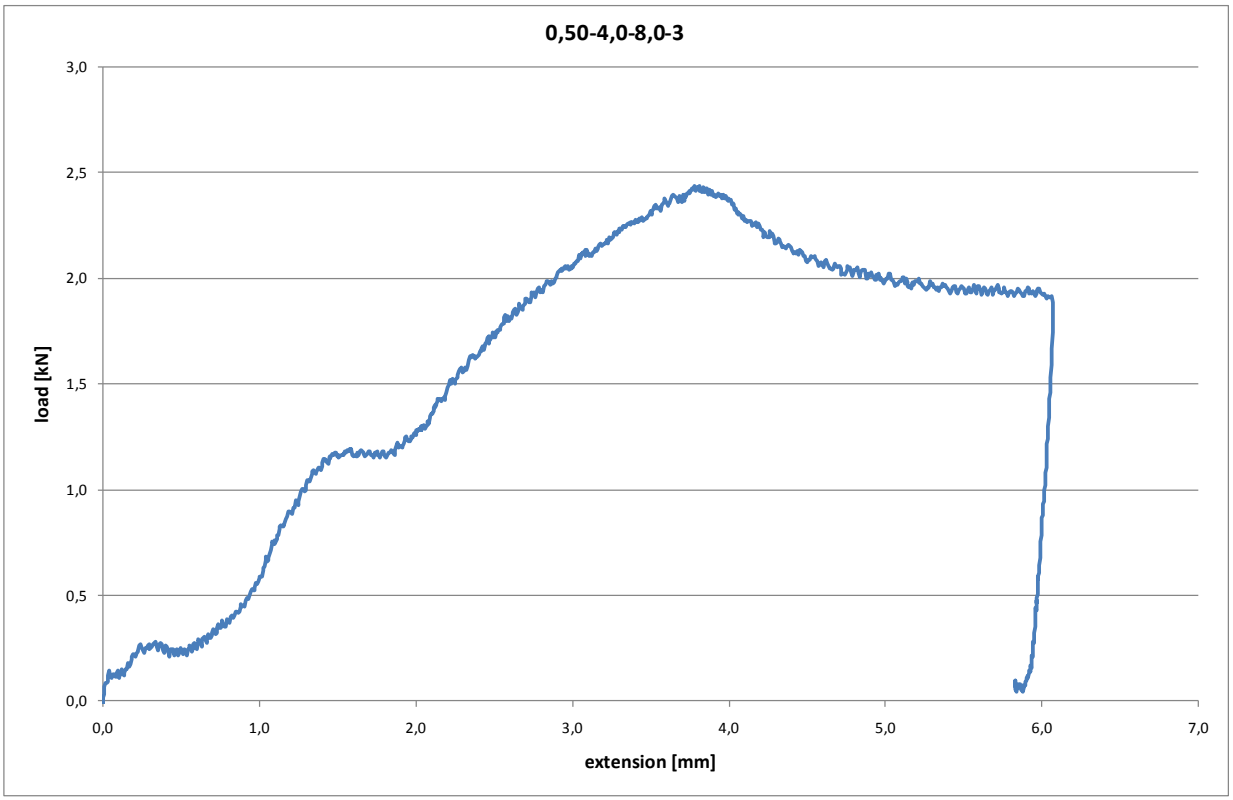
Thickness of face sheet: 0,50 mm

Thickness of substructure: 4,0 mm

Nominal diameter of fastener: 8,0 mm




0,50-4,0-8,0-2
load [kN]
extension [mm]
0,0
0,5
1,0
1,5
2,0
2,5
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

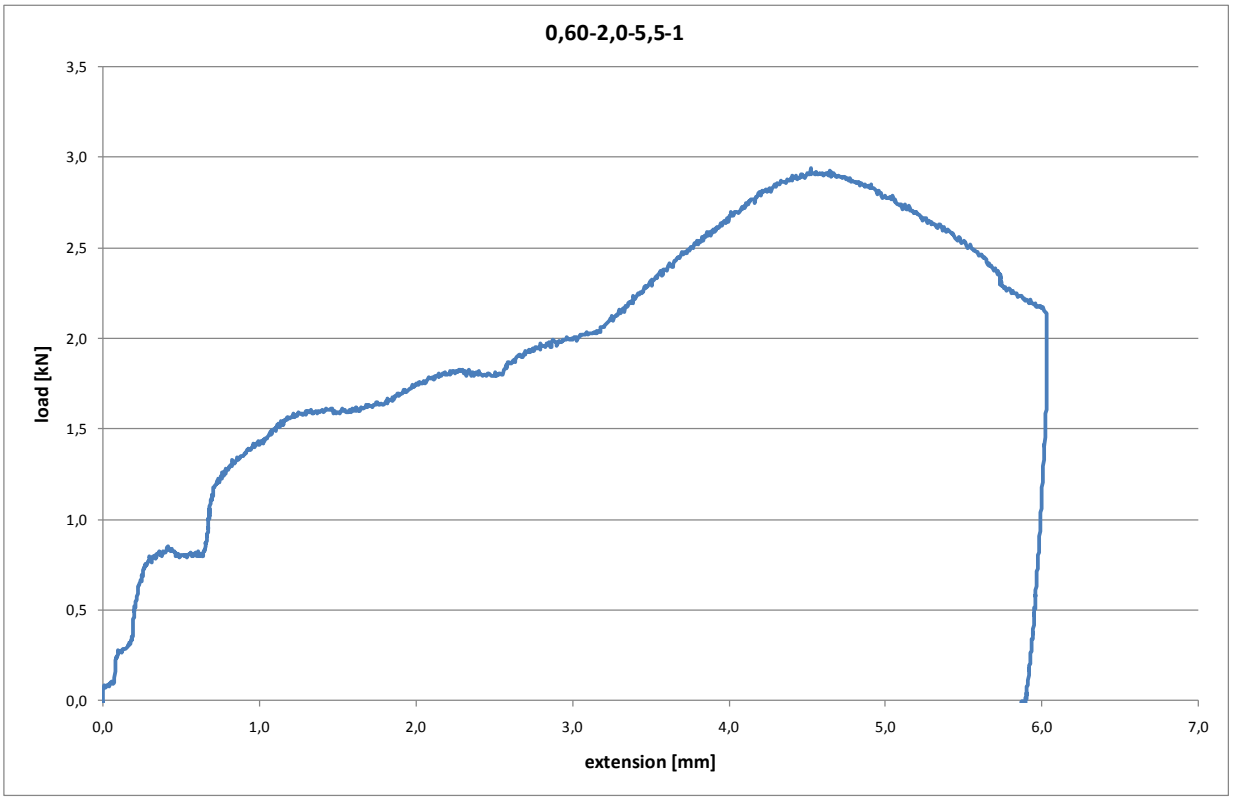

0,50-4,0-8,0-3
load [kN]
extension [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

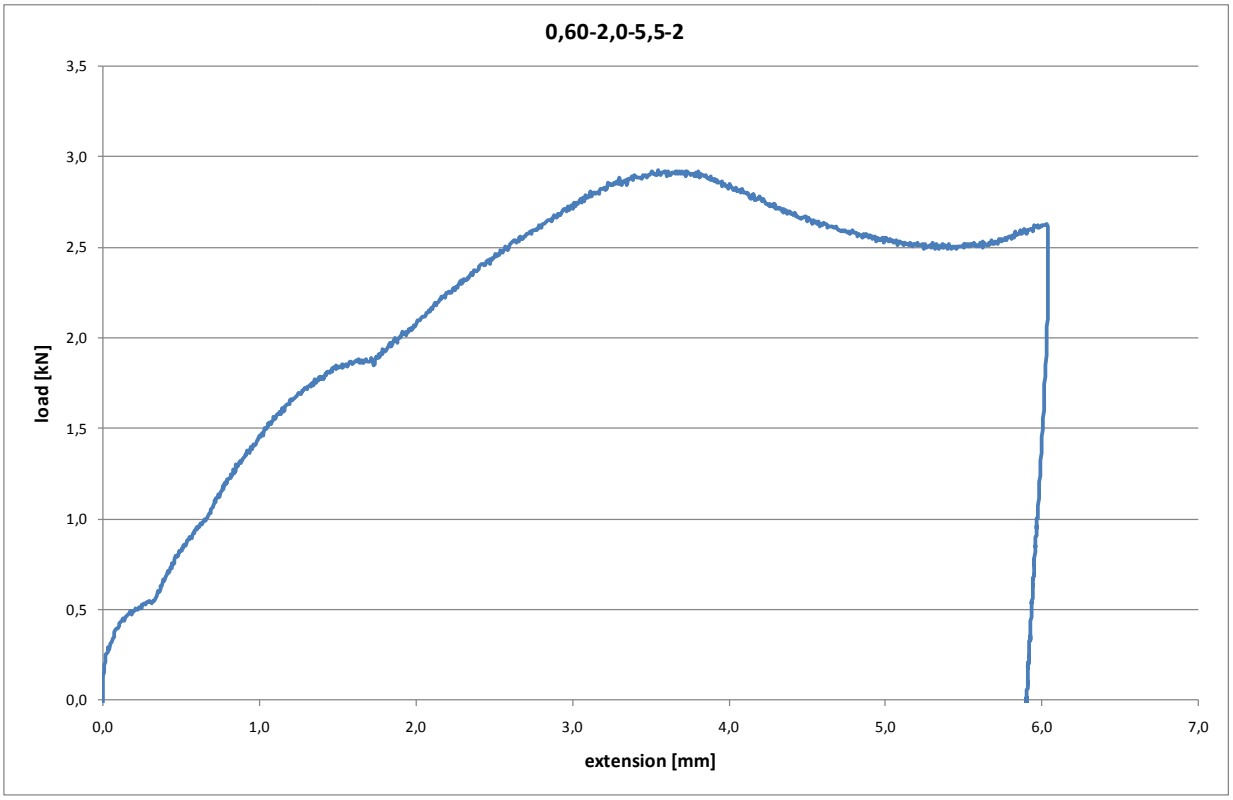
Full-scale tests

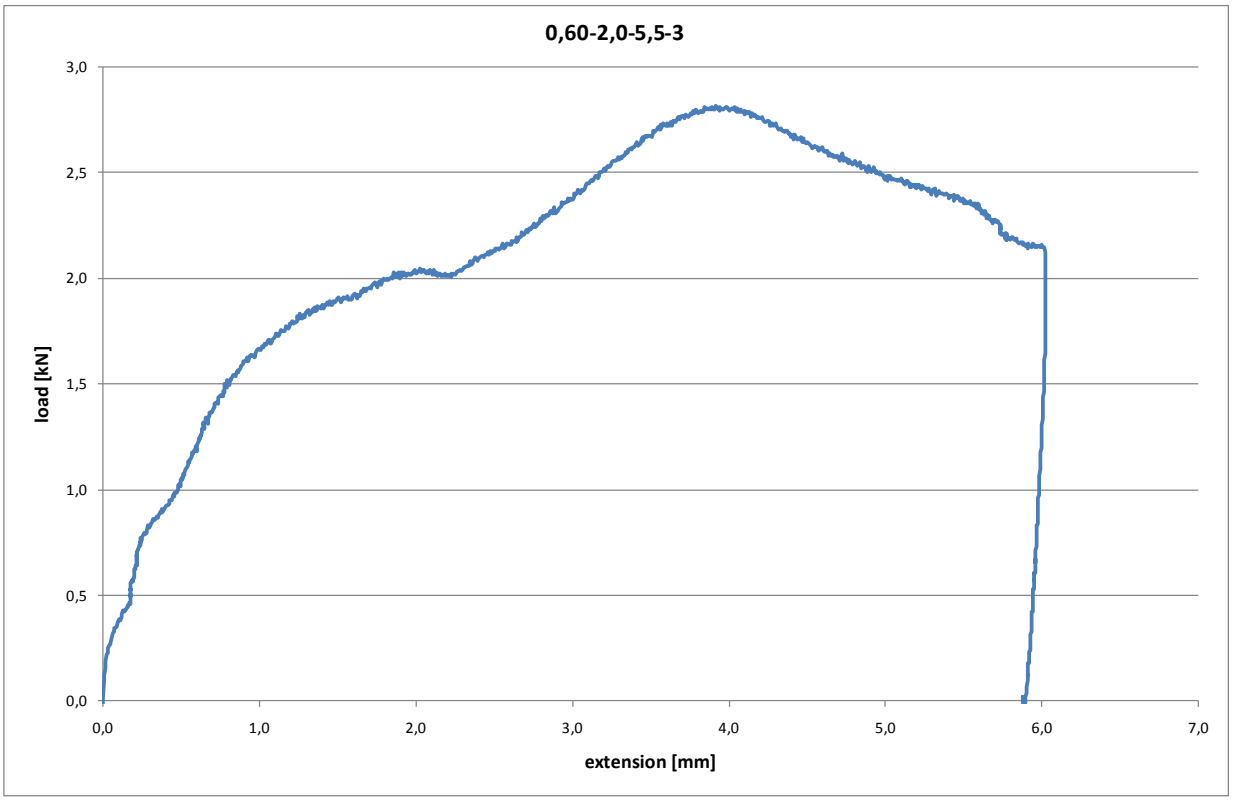
Thickness of face sheet: 0,60 mm

Thickness of substructure: 2,0 mm

Nominal diameter of fastener: 5,5 mm




0,60-2,0-5,5-2
load [kN]
extension [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

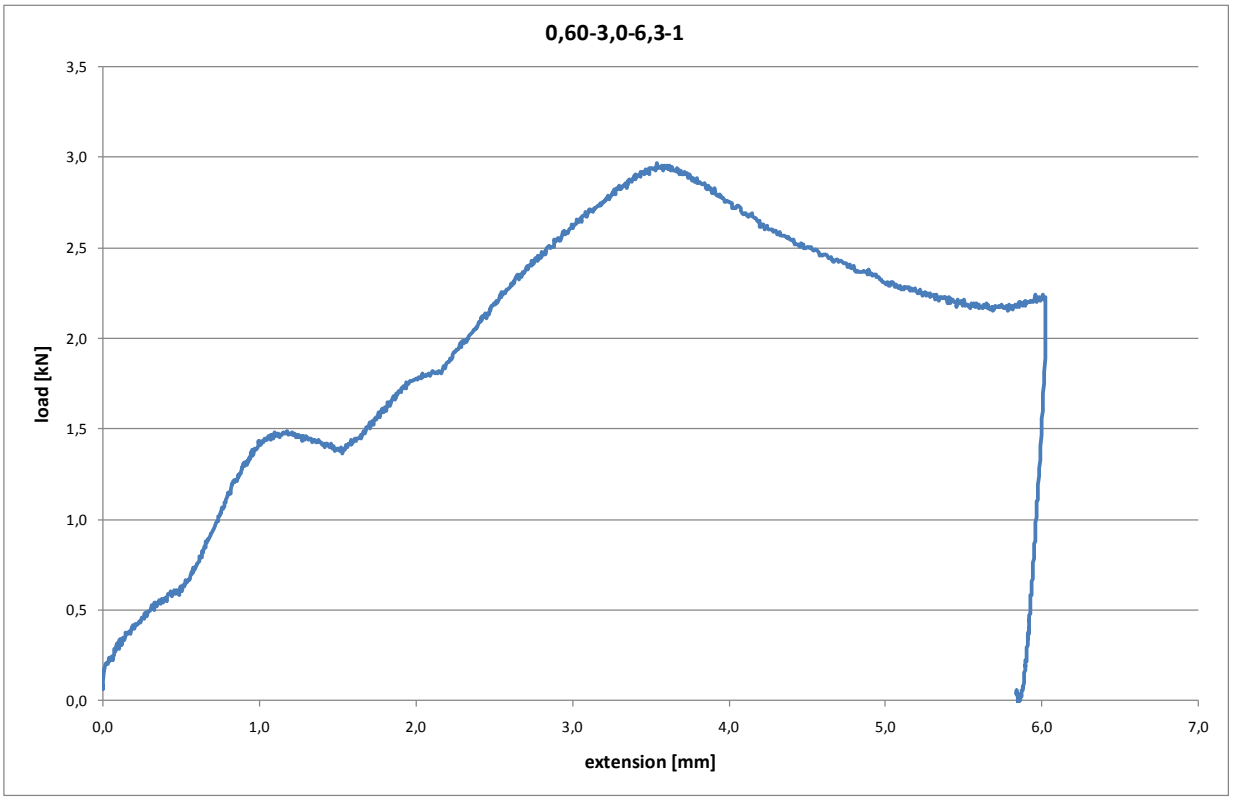

0,60-2,0-5,5-3
load [kN]
extension [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

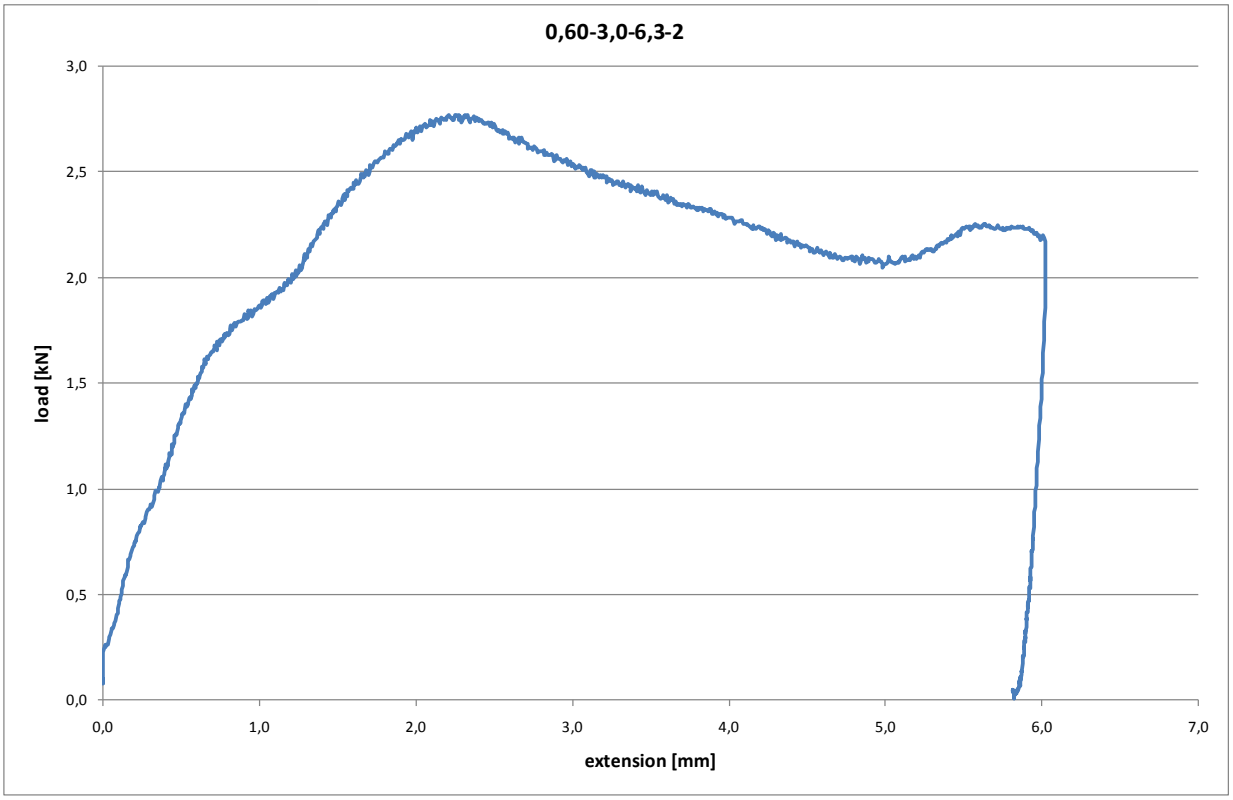
Full-scale tests

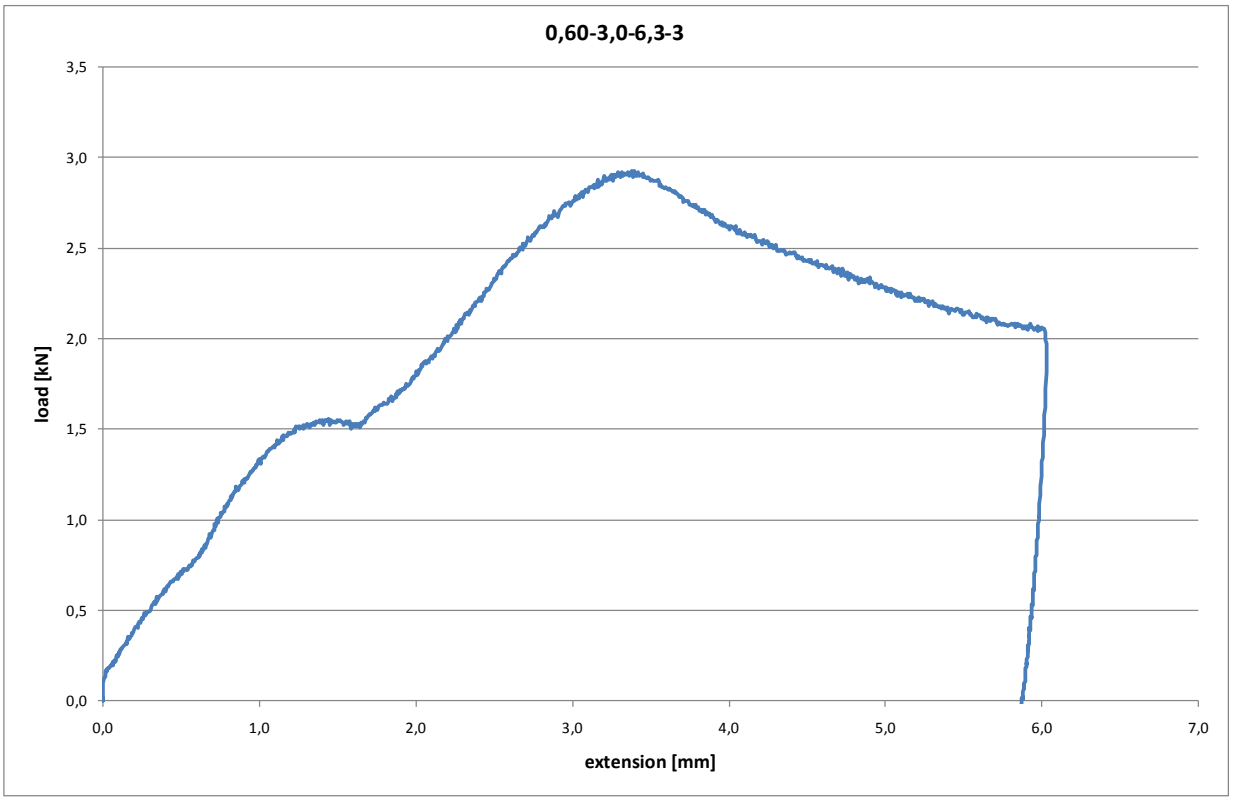
Thickness of face sheet: 0,60 mm

Thickness of substructure: 6,0 mm

Nominal diameter of fastener: 6,3 mm




0,60-3,0-6,3-2
load [kN]
extension [mm]
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

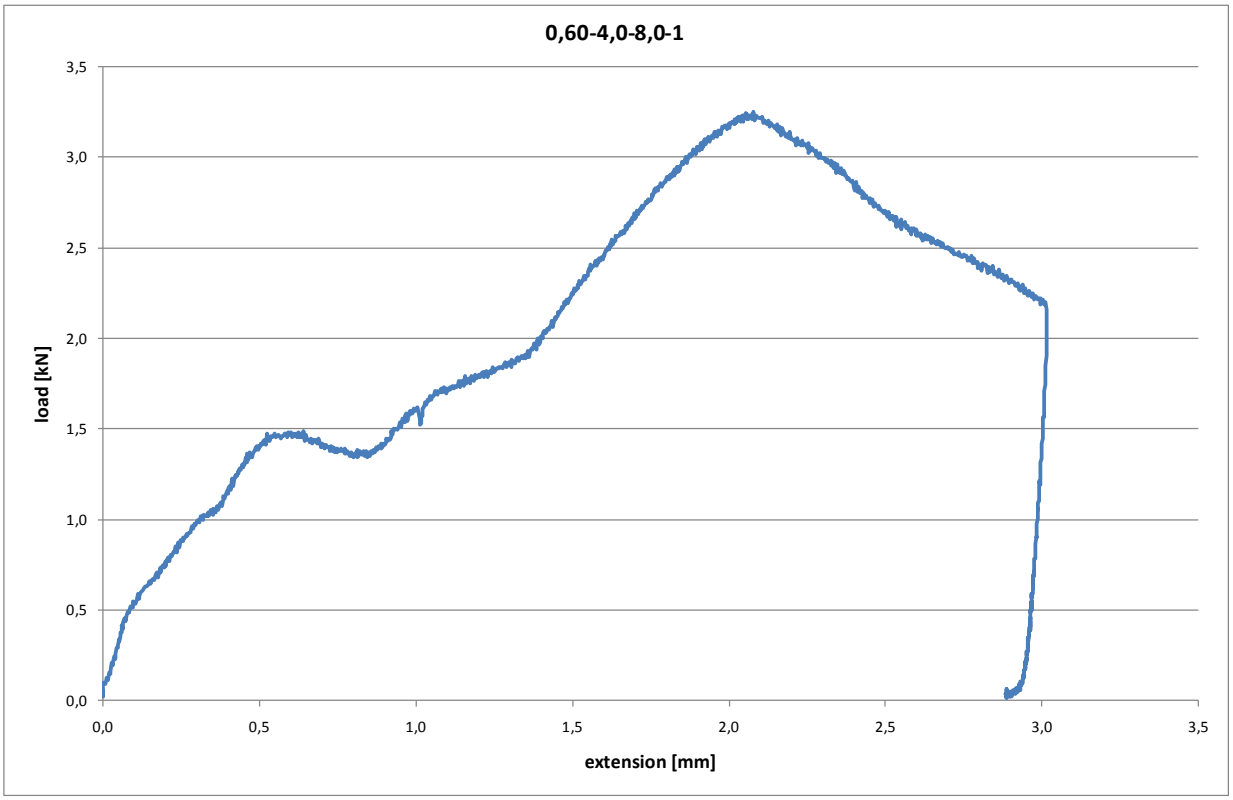

0,60-3,0-6,3-3
load [kN]
extension [mm]
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

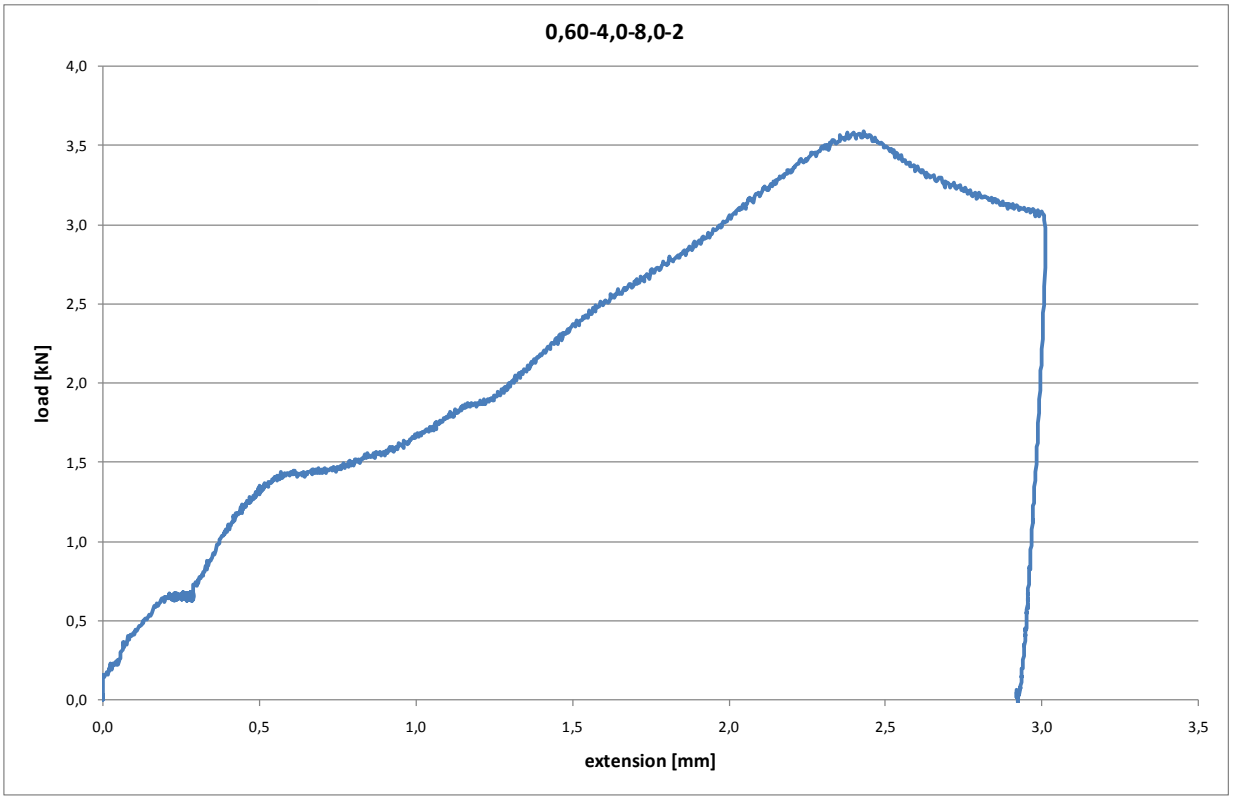
Full-scale tests

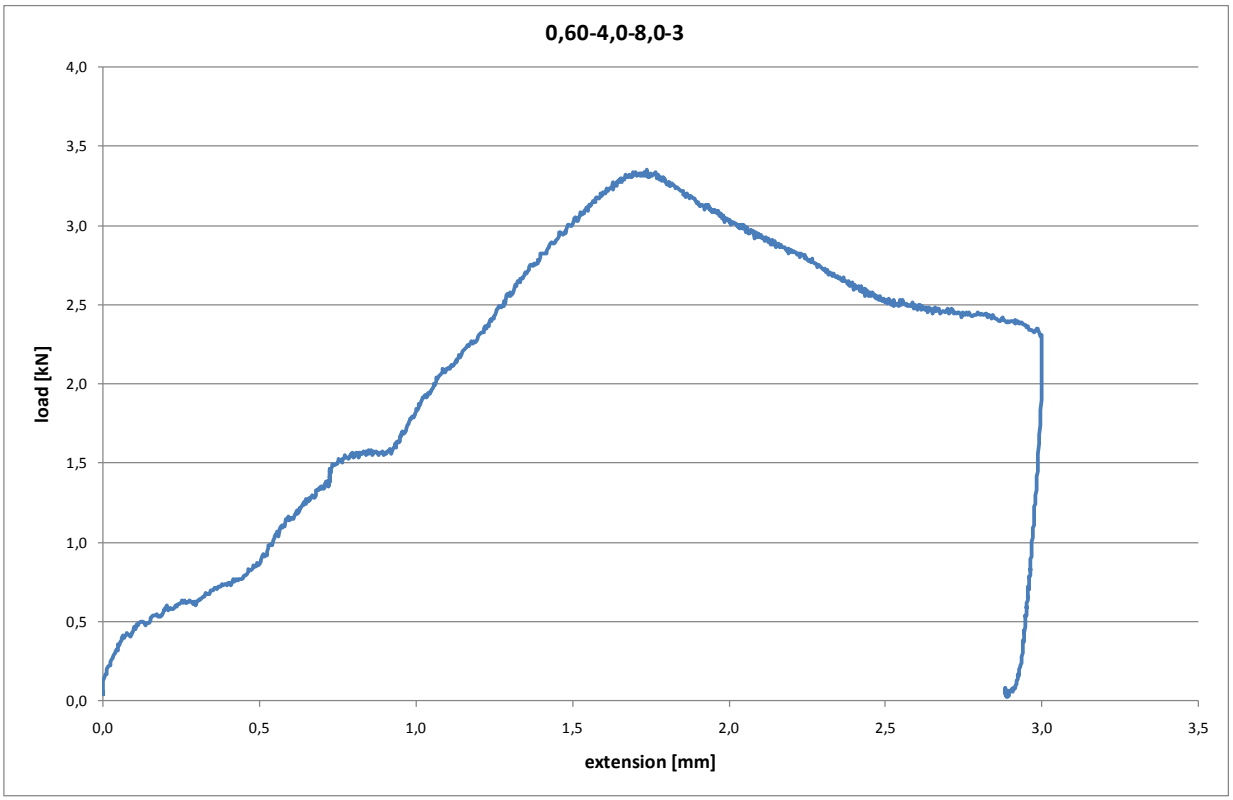
Thickness of face sheet: 0,60 mm

Thickness of substructure: 4,0 mm

Nominal diameter of fastener: 8,0 mm




0,60-4,0-8,0-2
load [kN]
extension [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0

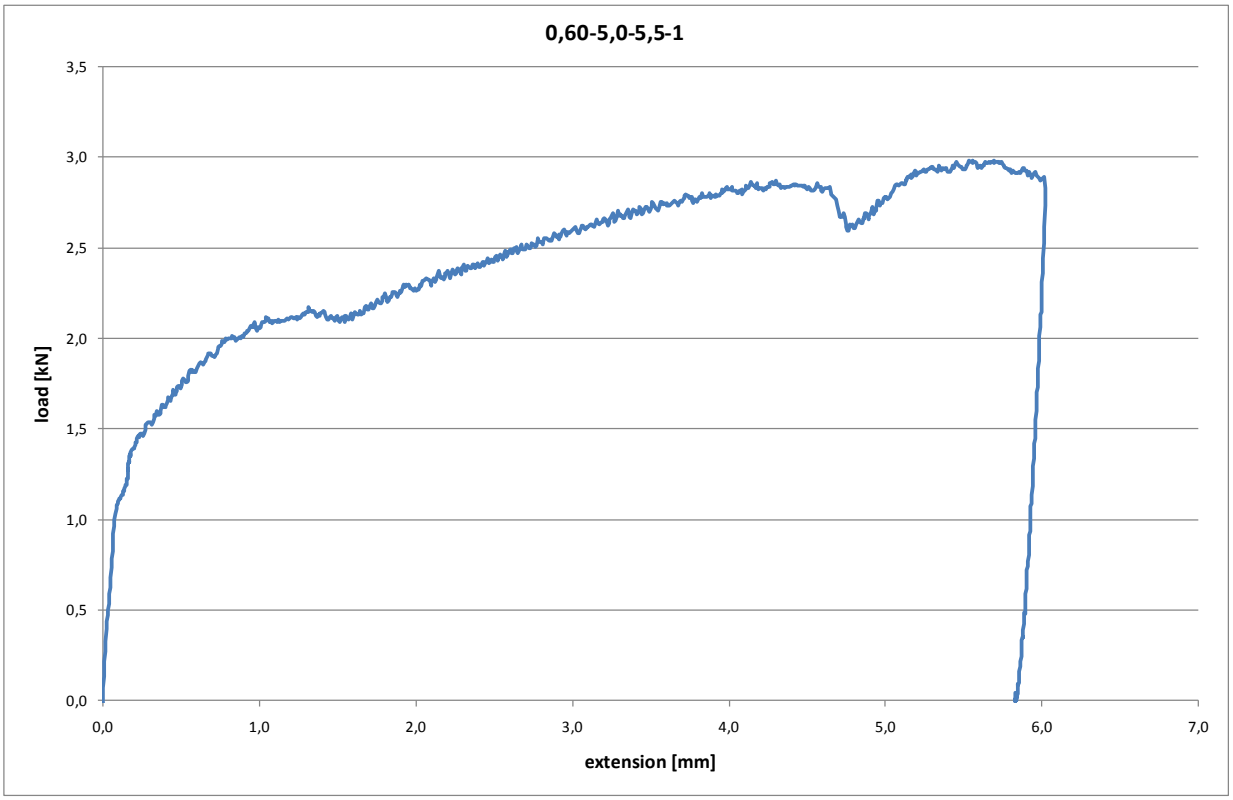

0,60-4,0-8,0-3
load [kN]
extension [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0

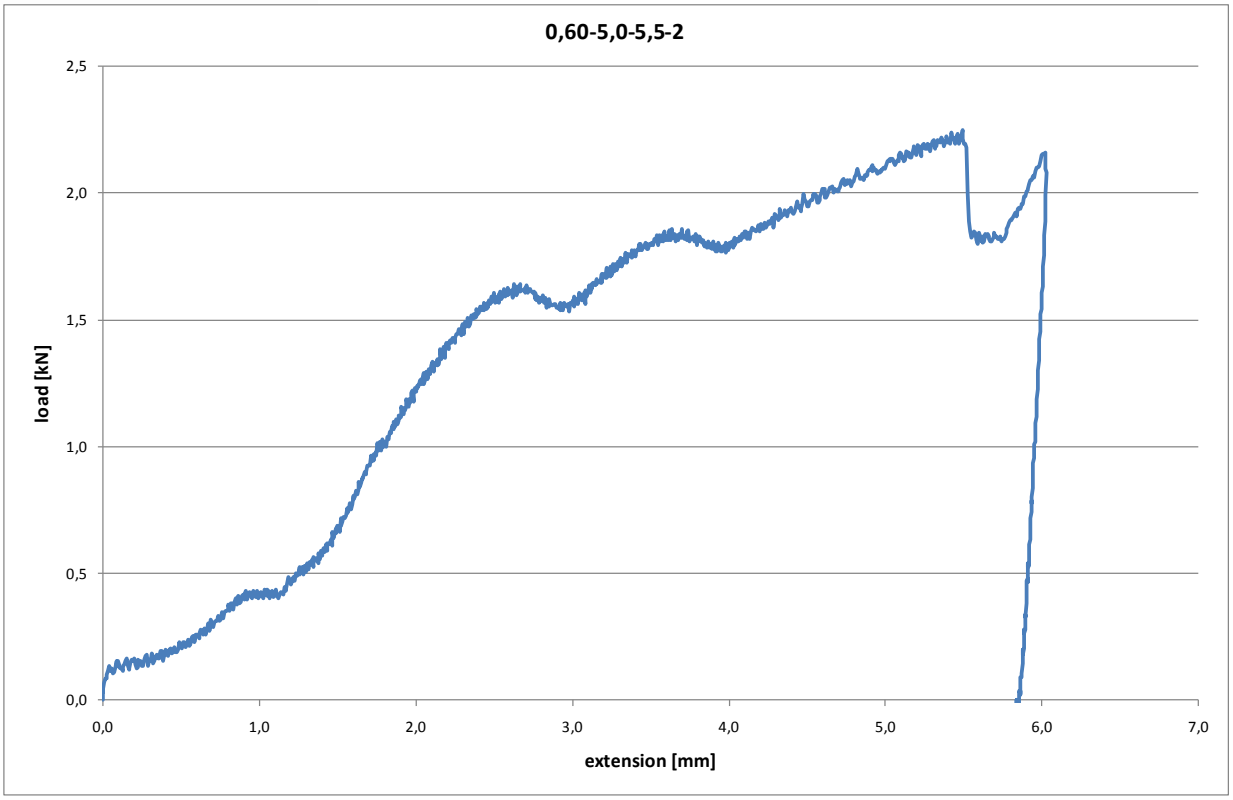
Full-scale tests

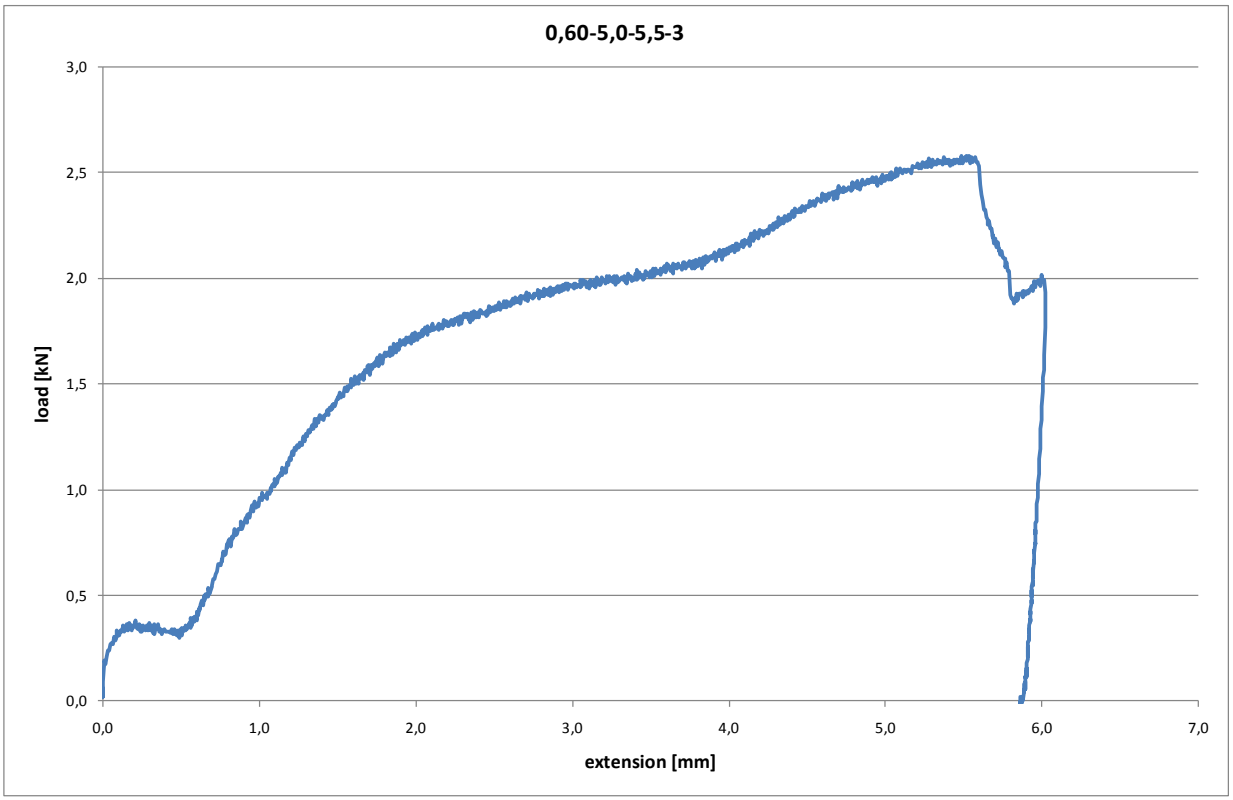
Thickness of face sheet: 0,60 mm

Thickness of substructure: 5,0 mm

Nominal diameter of fastener: 5,5 mm




0,60-5,0-5,5-2
load [kN]
extension [mm]
0,0
0,5
1,0
1,5
2,0
2,5
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

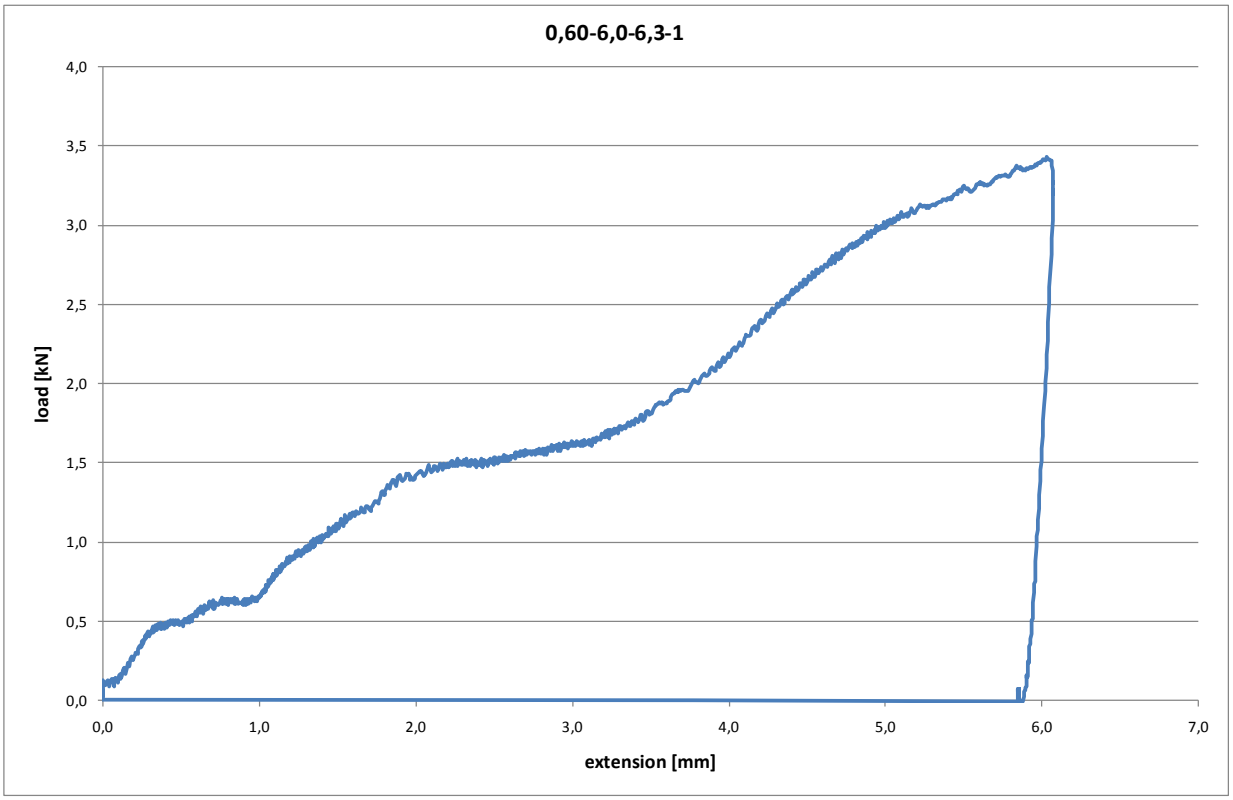

0,60-5,0-5,5-3
load [kN]
extension [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

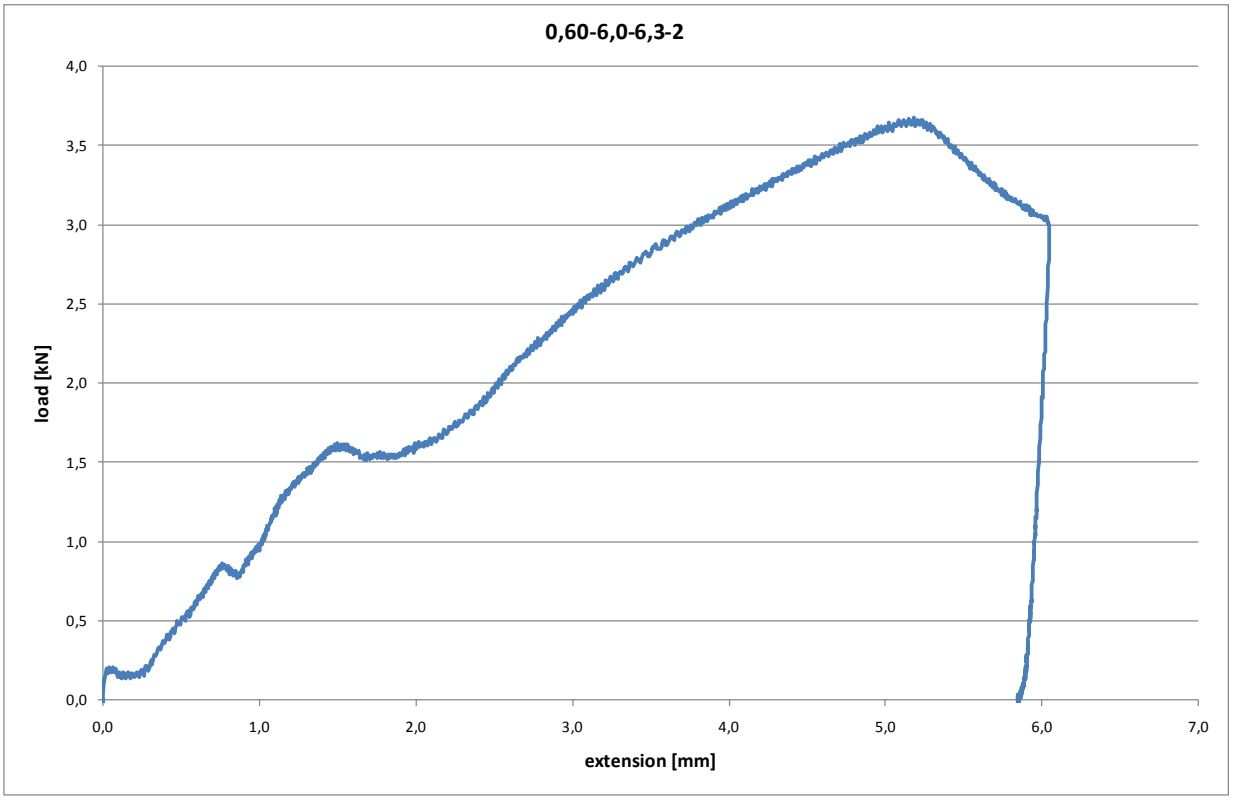
Full-scale tests

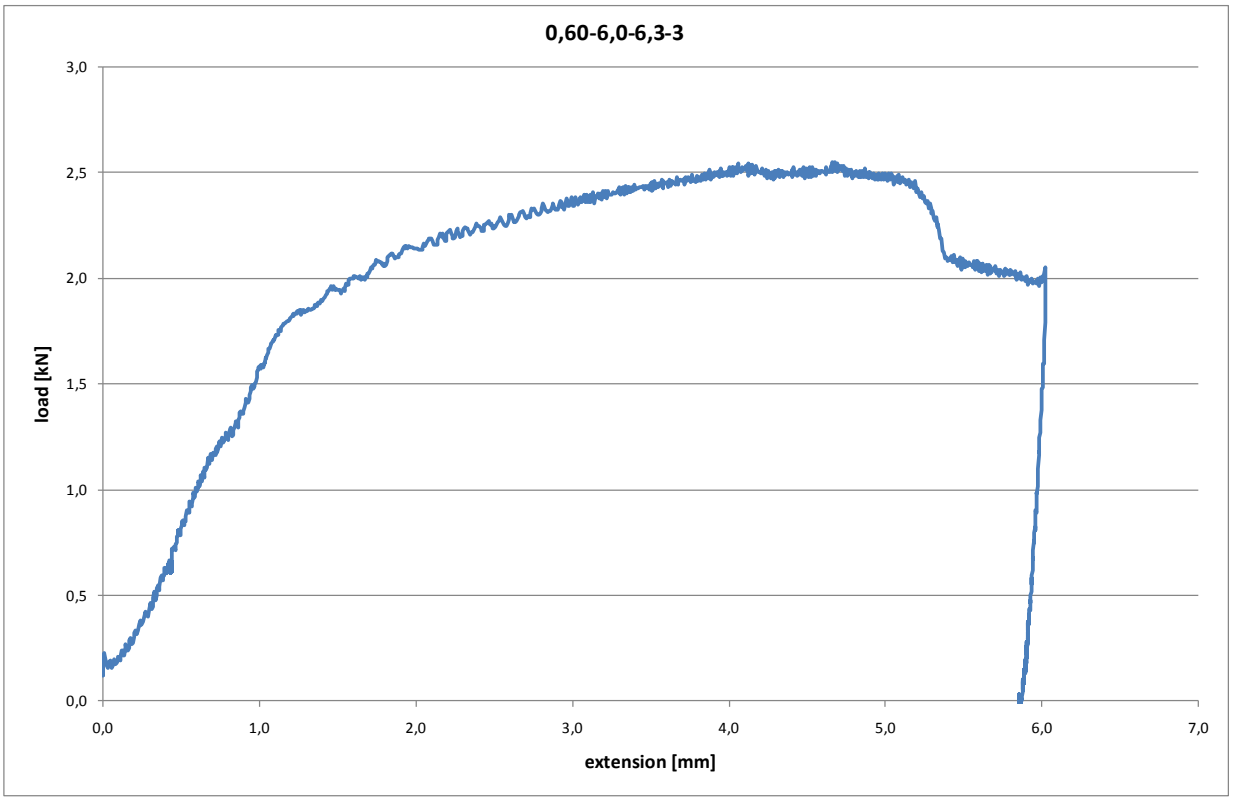
Thickness of face sheet: 0,60 mm

Thickness of substructure: 6,0 mm

Nominal diameter of fastener: 6,3 mm




0,60-6,0-6,3-2
load [kN]
extension [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

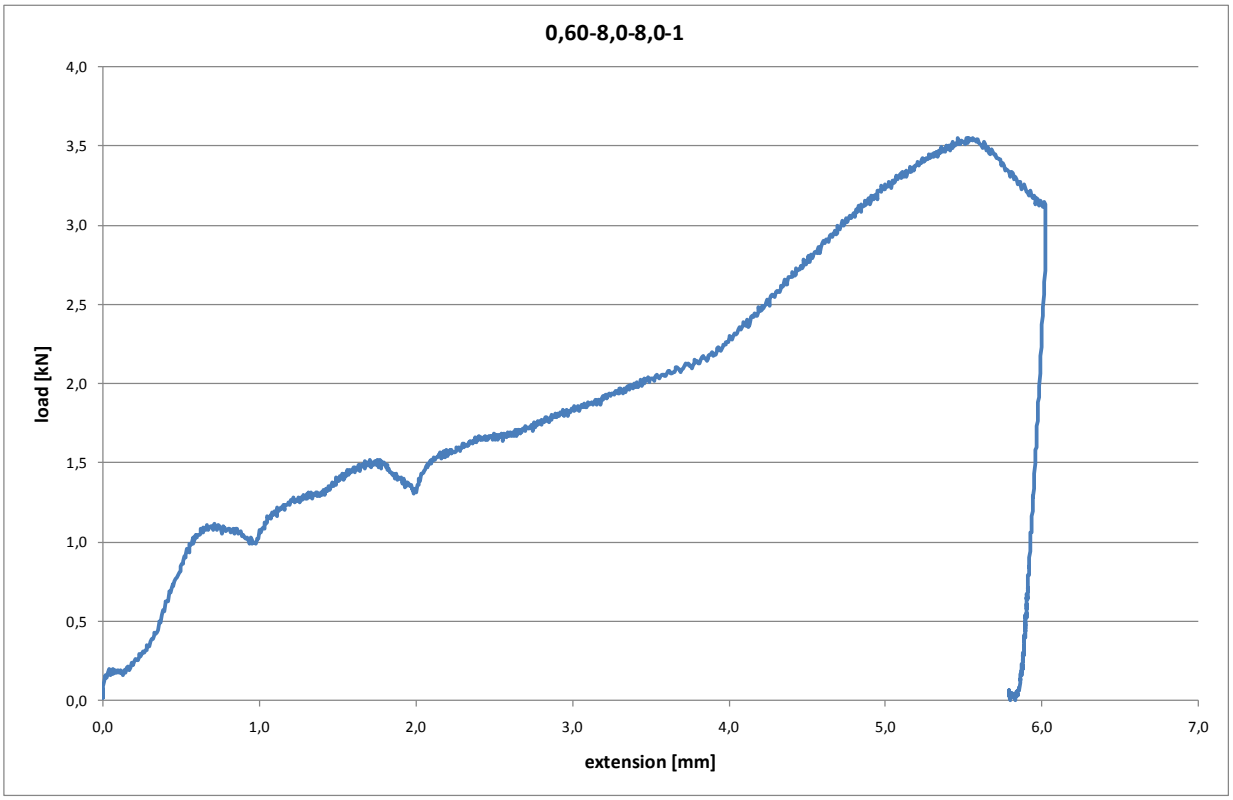

0,60-6,0-6,3-3
load [kN]
extension [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

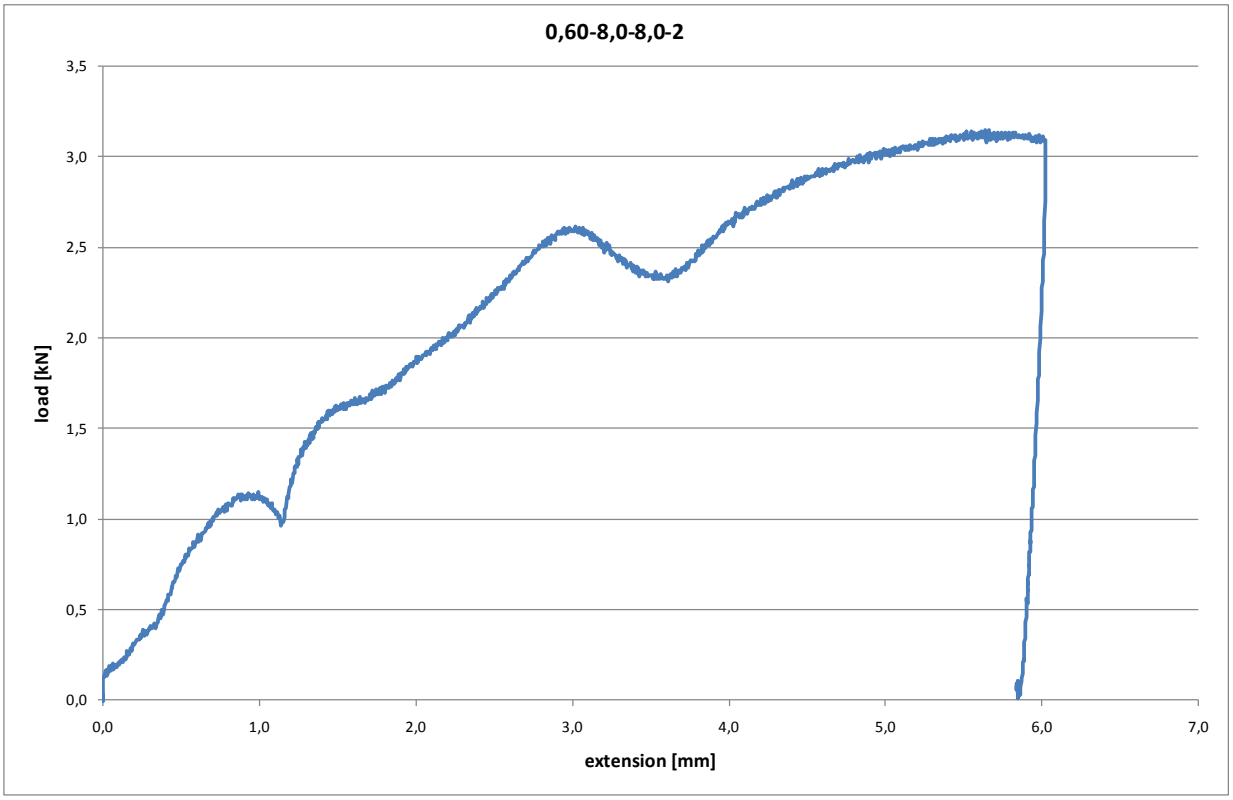
Full-scale tests

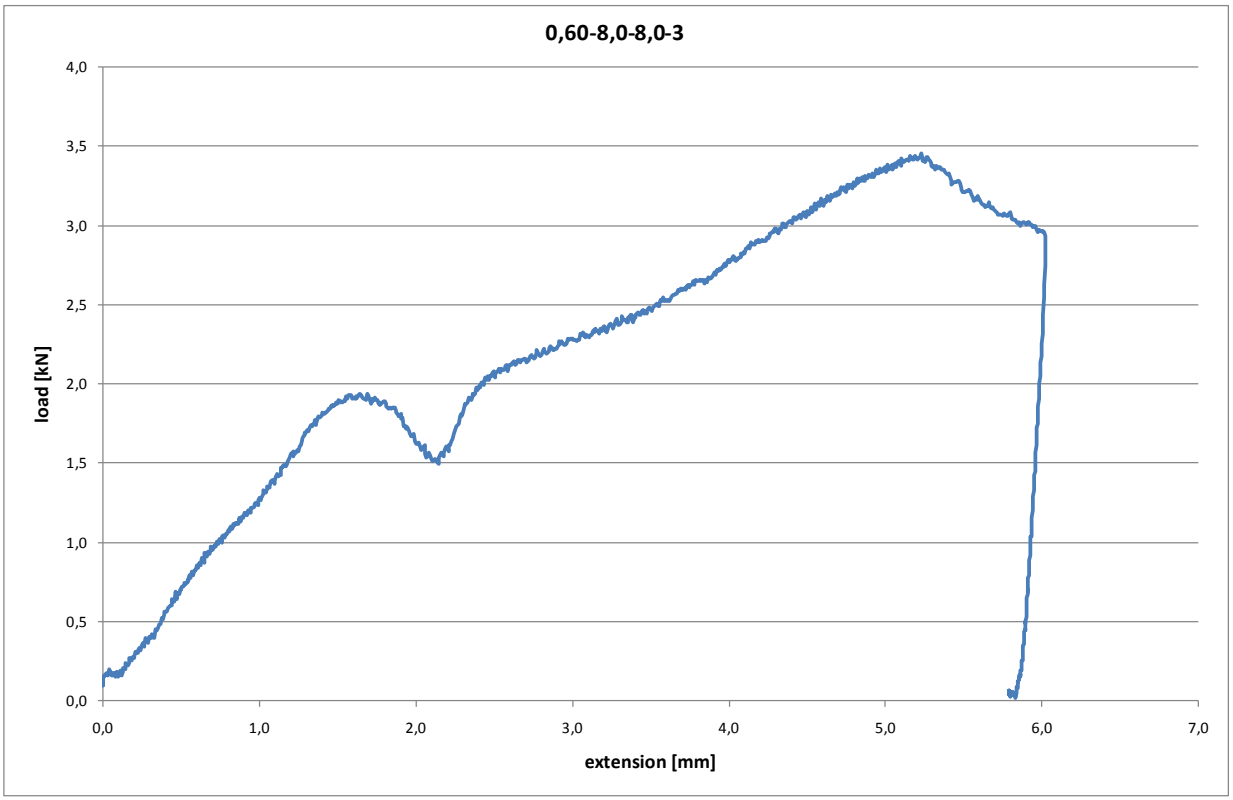
Thickness of face sheet: 0,60 mm

Thickness of substructure: 8,0 mm

Nominal diameter of fastener: 8,0 mm




0,60-8,0-8,0-2
load [kN]
extension [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

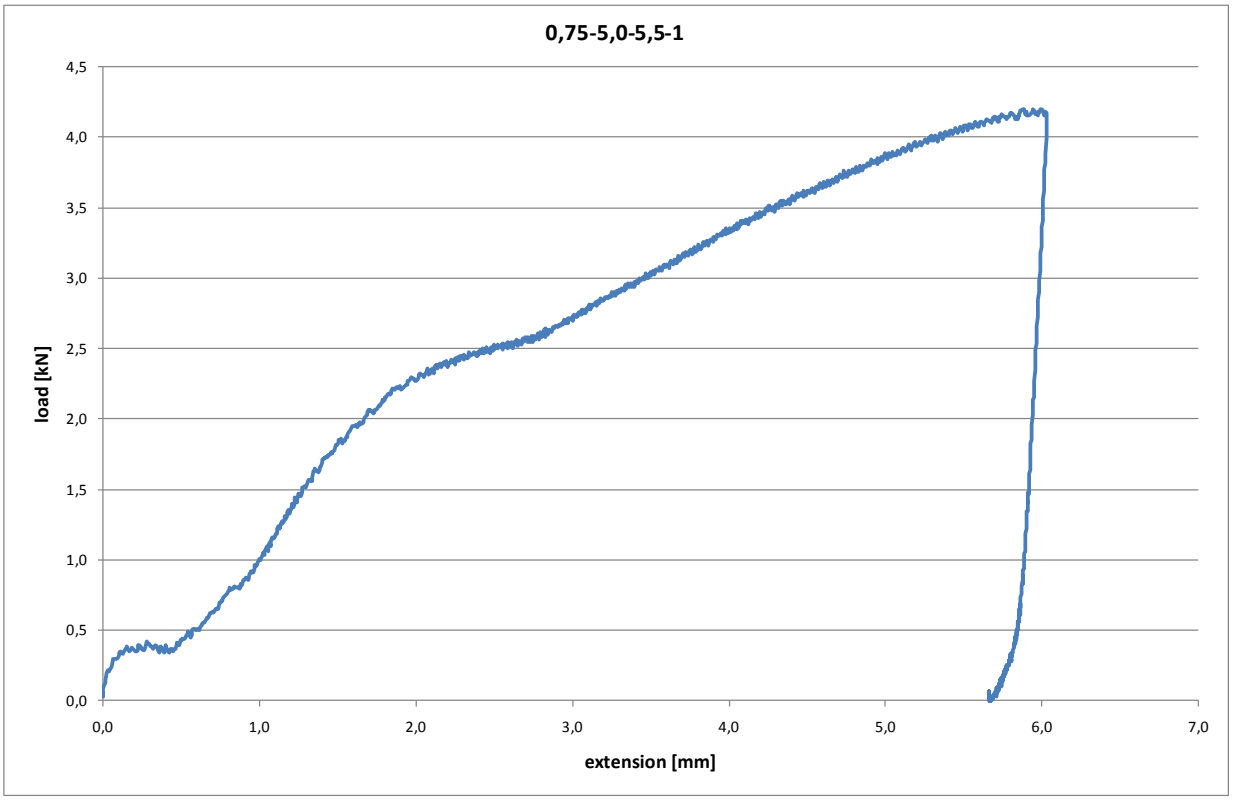

0,60-8,0-8,0-3
load [kN]
extension [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

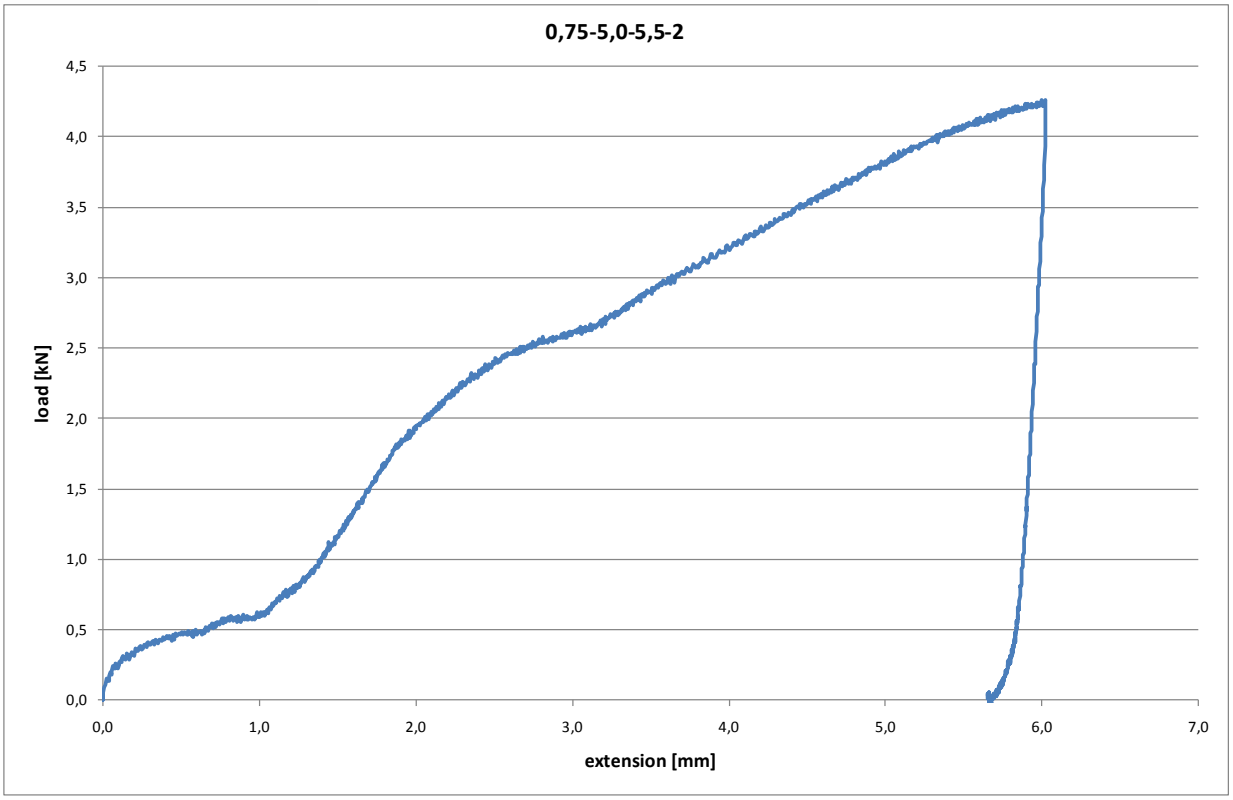
Full-scale tests

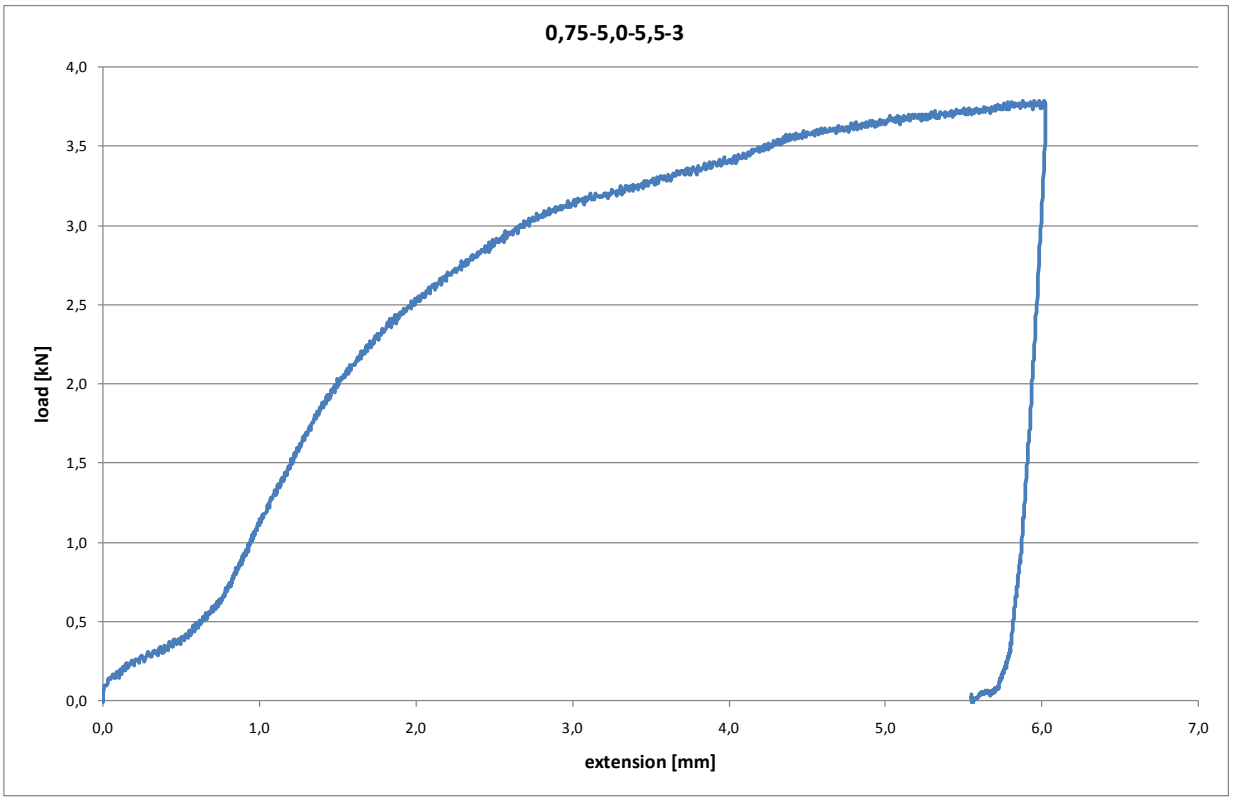
Thickness of face sheet: 0,75 mm

Thickness of substructure: 5,0 mm

Nominal diameter of fastener: 5,5 mm




0,75-5,0-5,5-2
load [kN]
extension [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
4,5
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

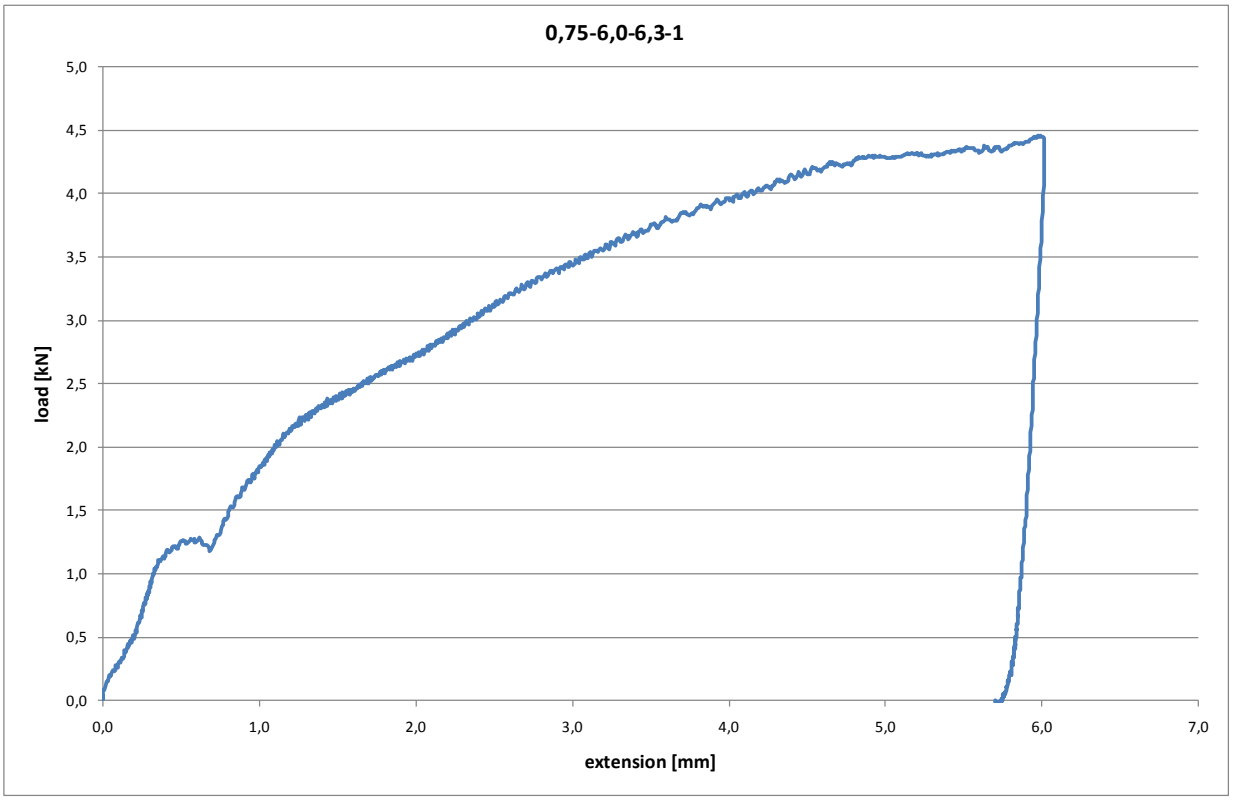

0,75-5,0-5,5-3
load [kN]
extension [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

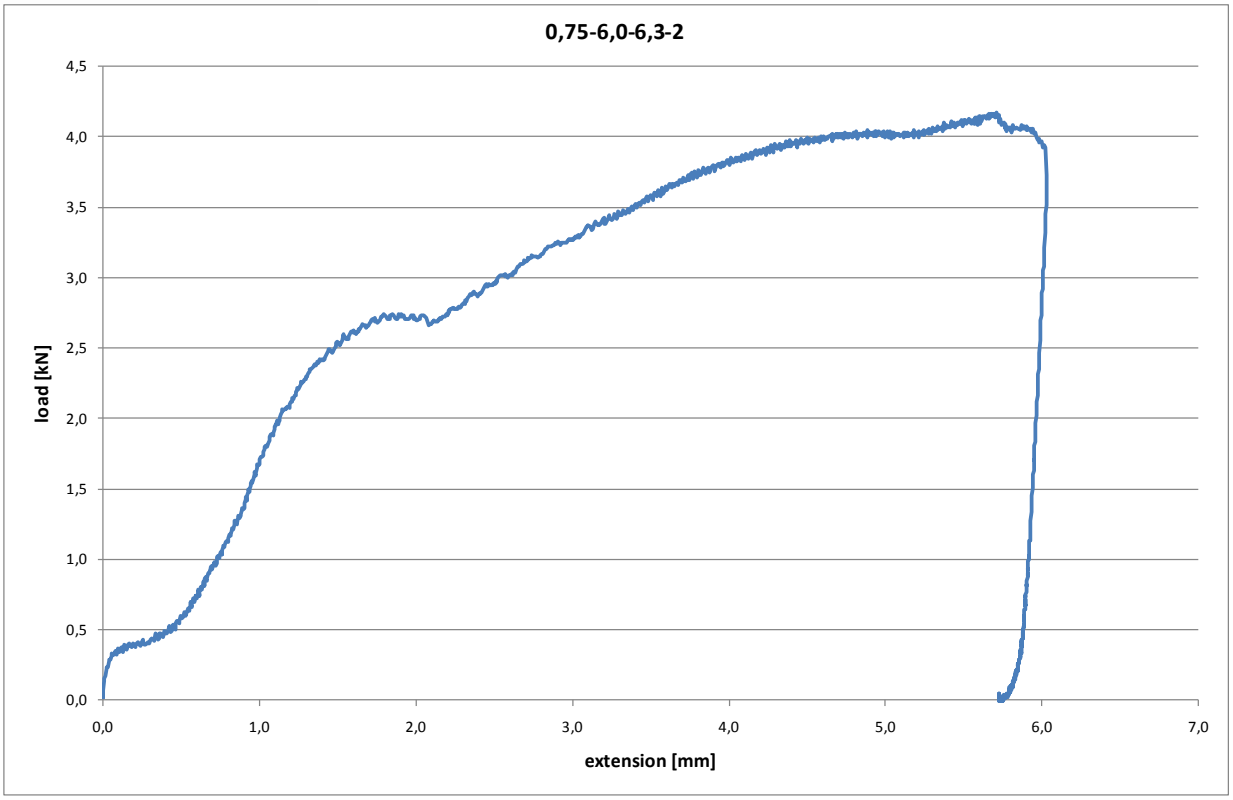
Full-scale tests

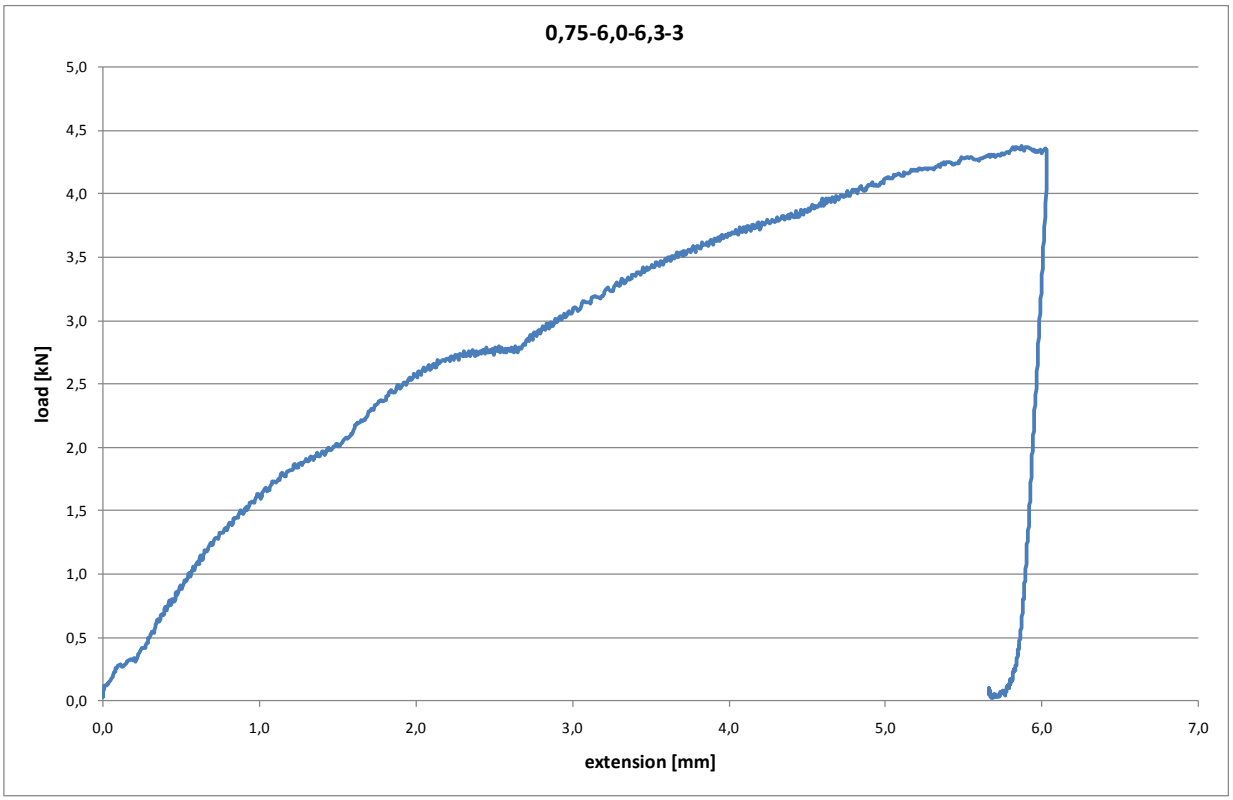
Thickness of face sheet: 0,75 mm

Thickness of substructure: 6,0 mm

Nominal diameter of fastener: 6,3 mm




0,75-6,0-6,3-2
load [kN]
extension [mm]
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
4,5
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0


0,75-6,0-6,3-3
load [kN]
extension [mm]
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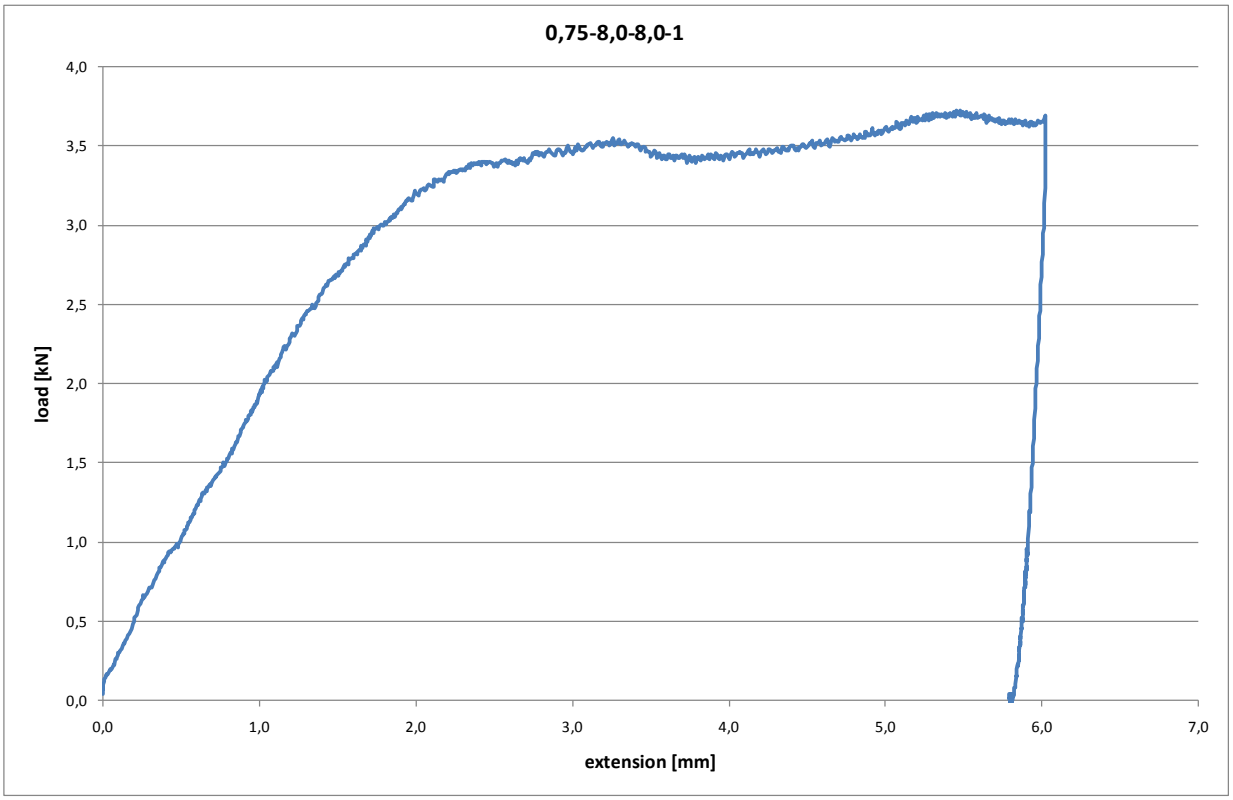
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
4,5
5,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

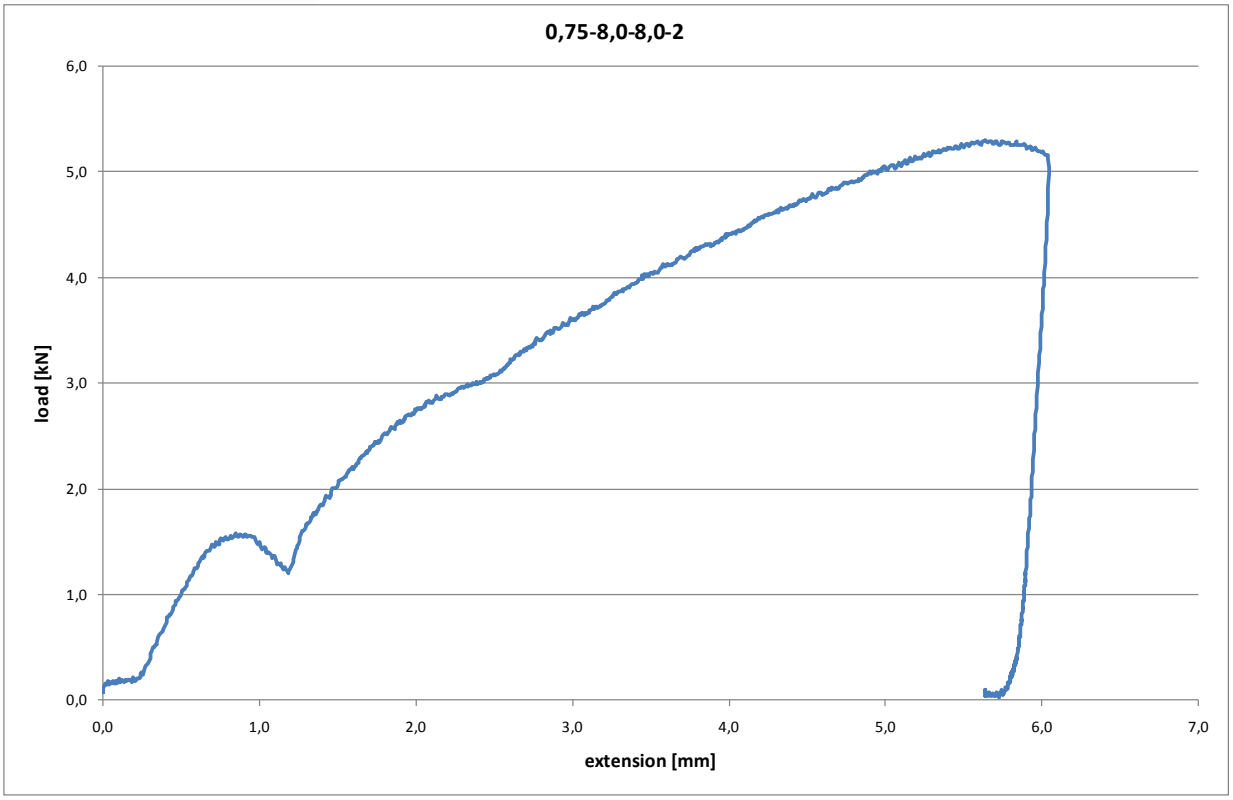
Full-scale tests

Thickness of face sheet: 0,75 mm

Thickness of substructure: 8,0 mm

Nominal diameter of fastener: 8,0 mm




0,75-8,0-8,0-2
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extension [mm]
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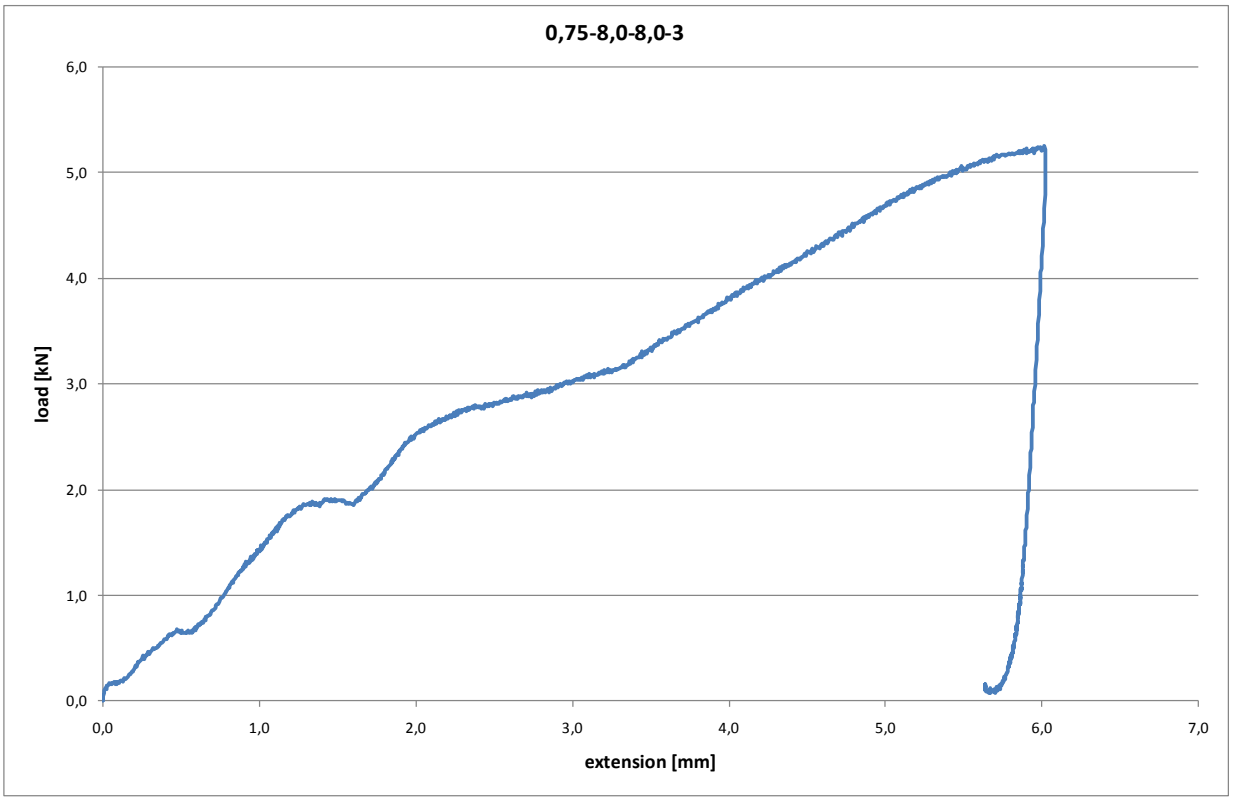
2,0
3,0
4,0
5,0
6,0
7,0

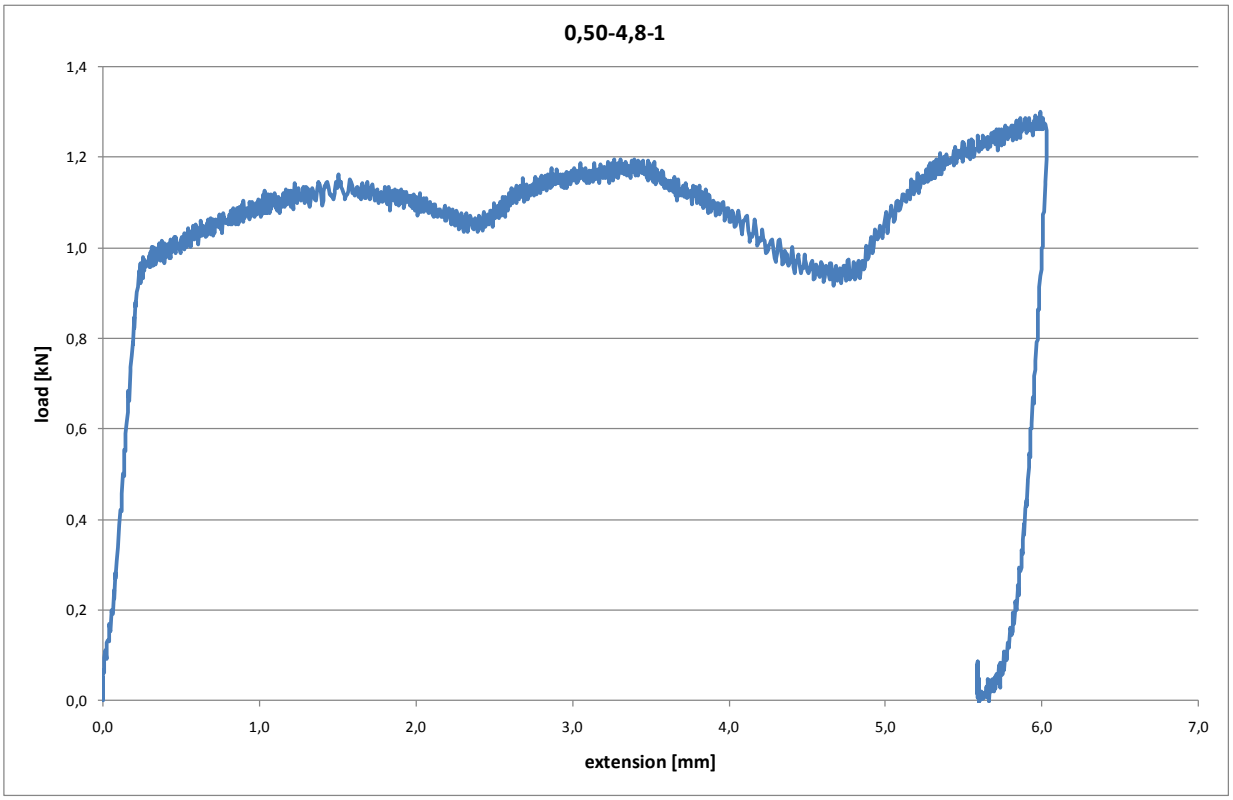

0,75-8,0-8,0-3
load [kN]
extension [mm]
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

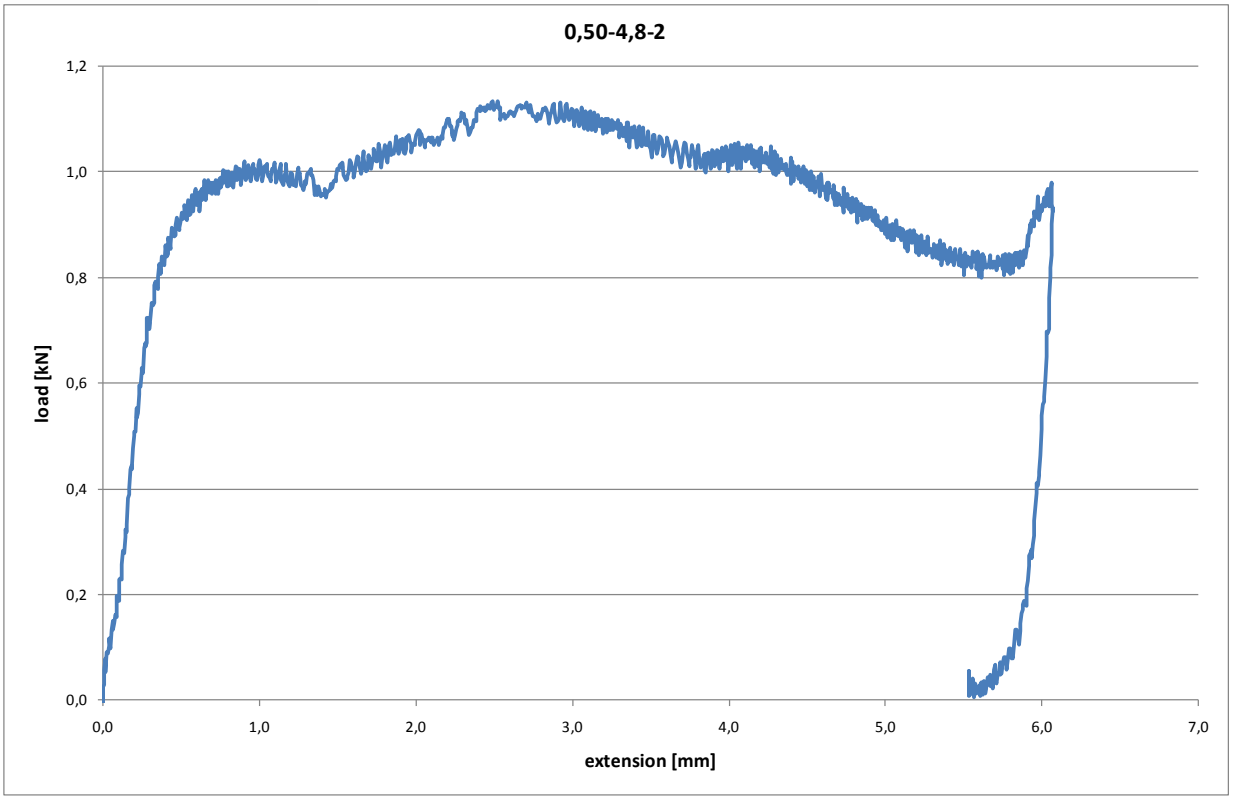
Test on connections of longitudinal joints

Thickness of face sheet: 0,50 mm

Nominal diameter of fastener: 4,8 mm

Connection without sealing tape

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extension [mm]
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0,4
0,6
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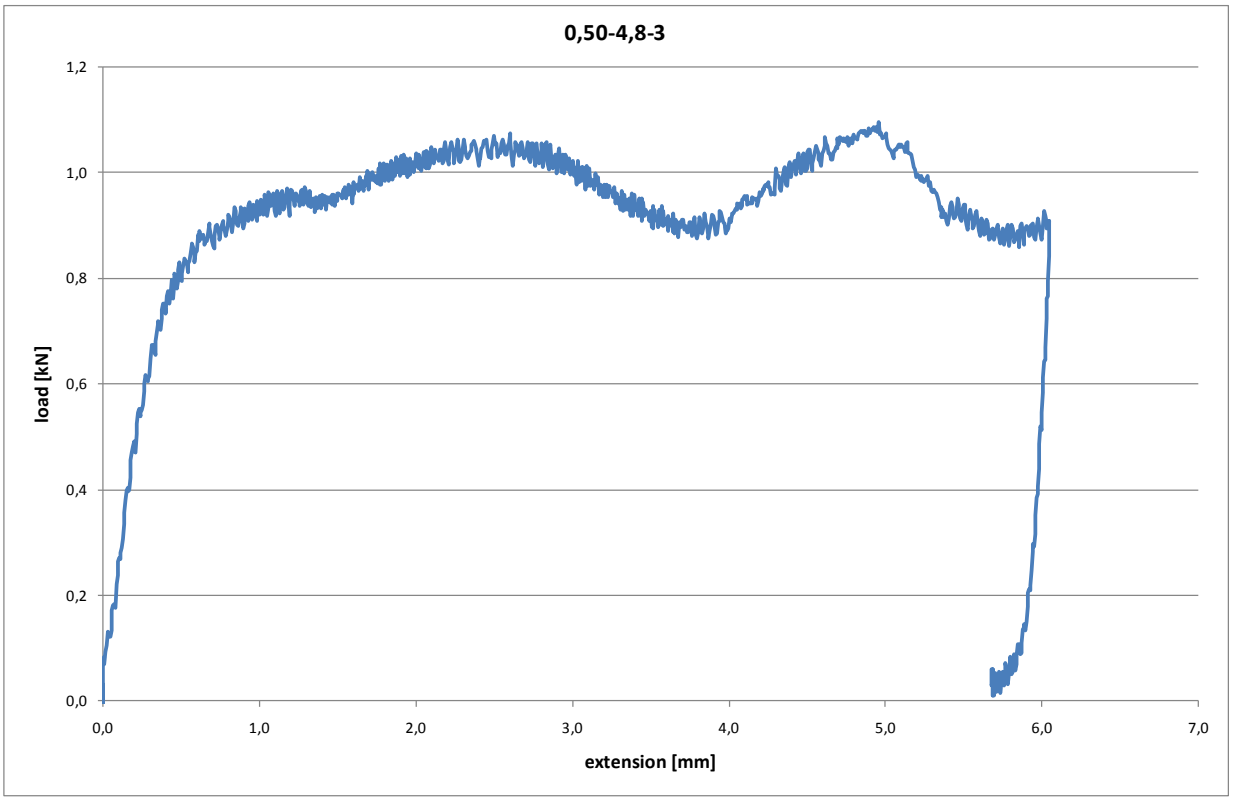
1,2
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0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load [kN]
extension [mm]
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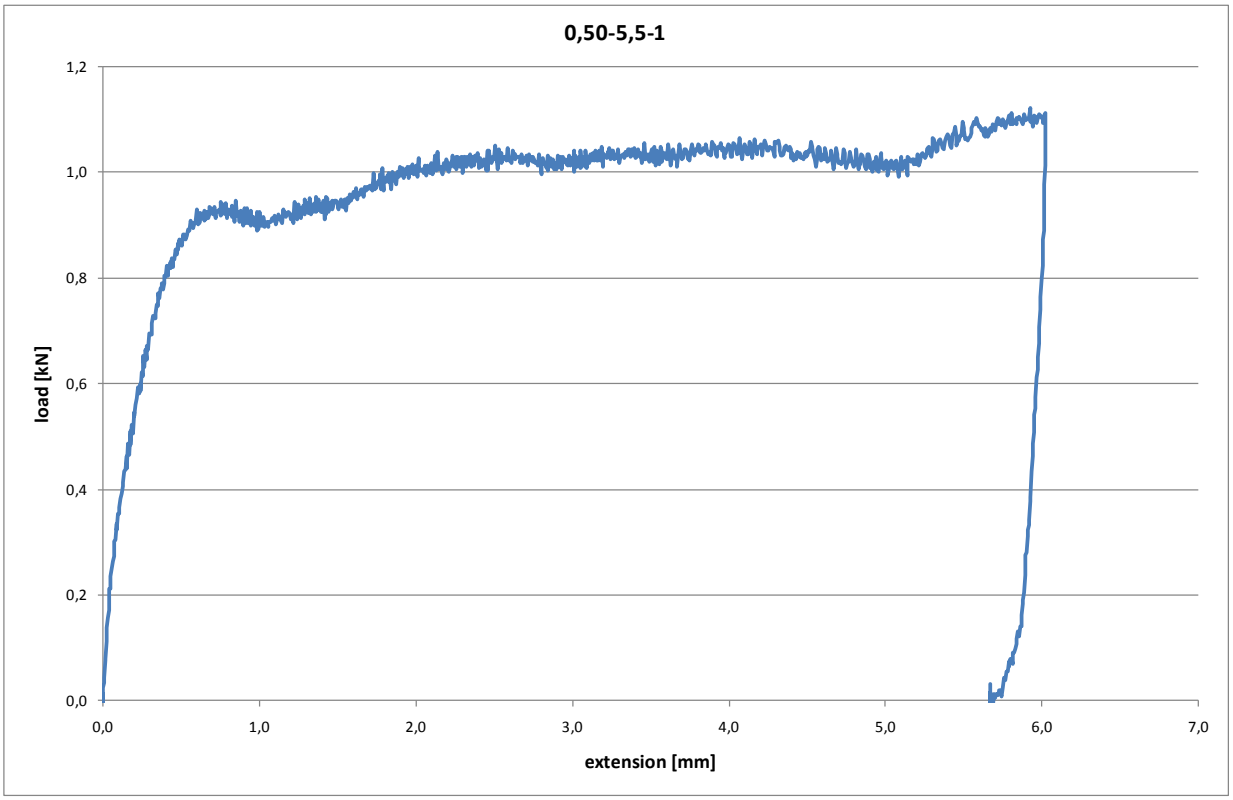
0,2
0,4
0,6
0,8
1,0
1,2
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

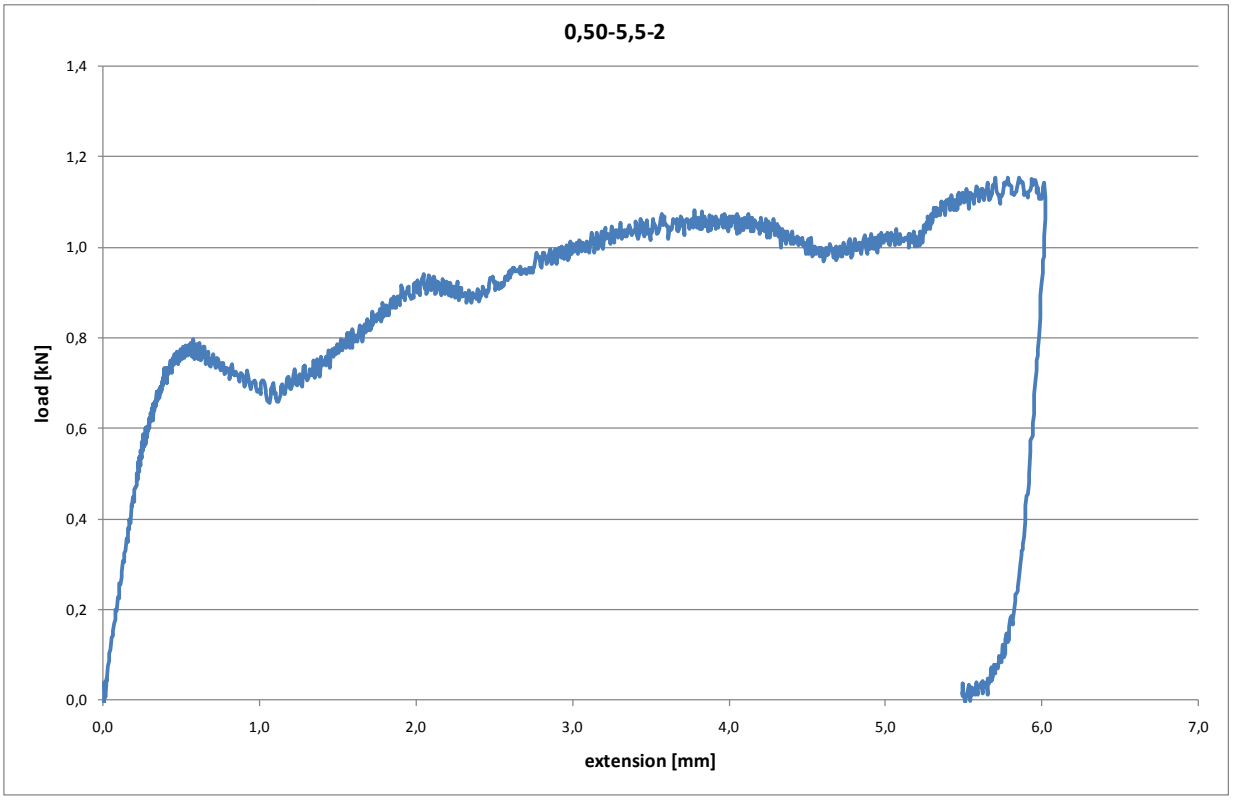
Test on connections of longitudinal joints

Thickness of face sheet: 0,50 mm

Nominal diameter of fastener: 5,5 mm

Connection without sealing tape

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0,2
0,4
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1,2
1,4
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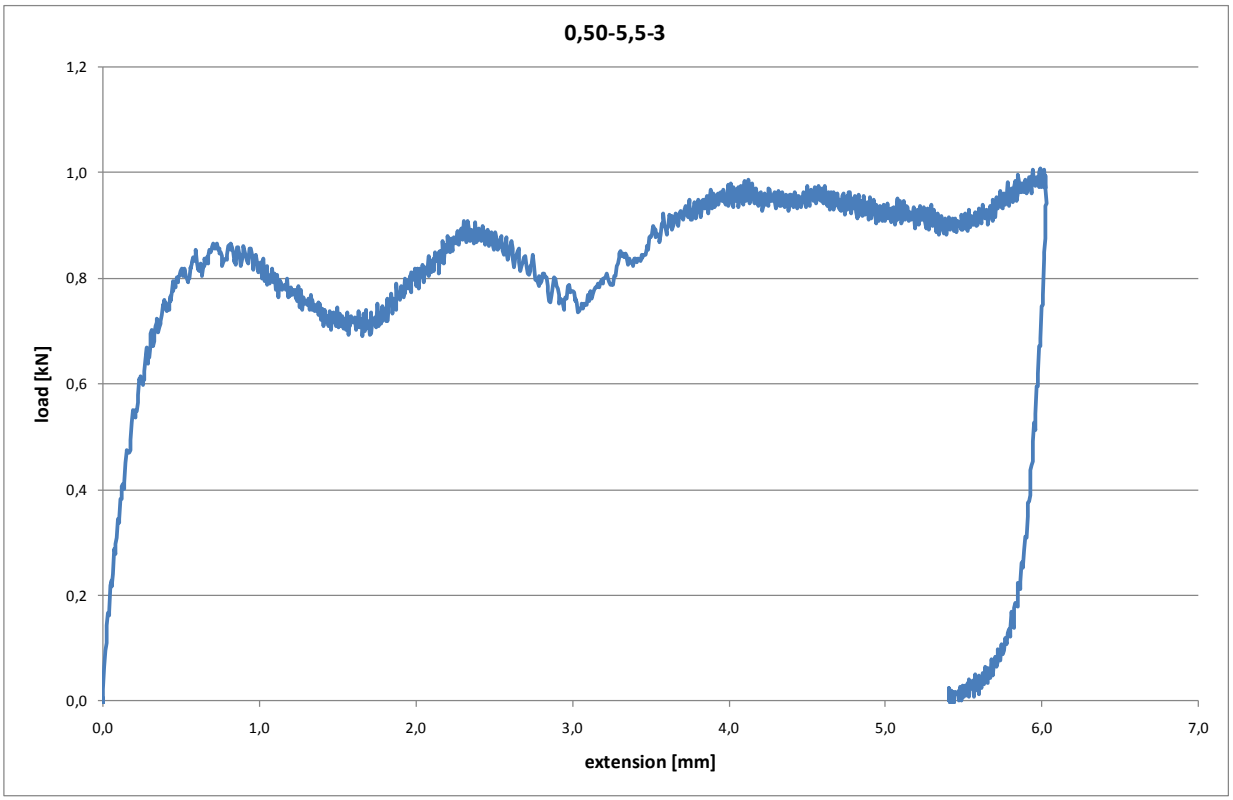
1,0
2,0
3,0
4,0
5,0
6,0
7,0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extension [mm]
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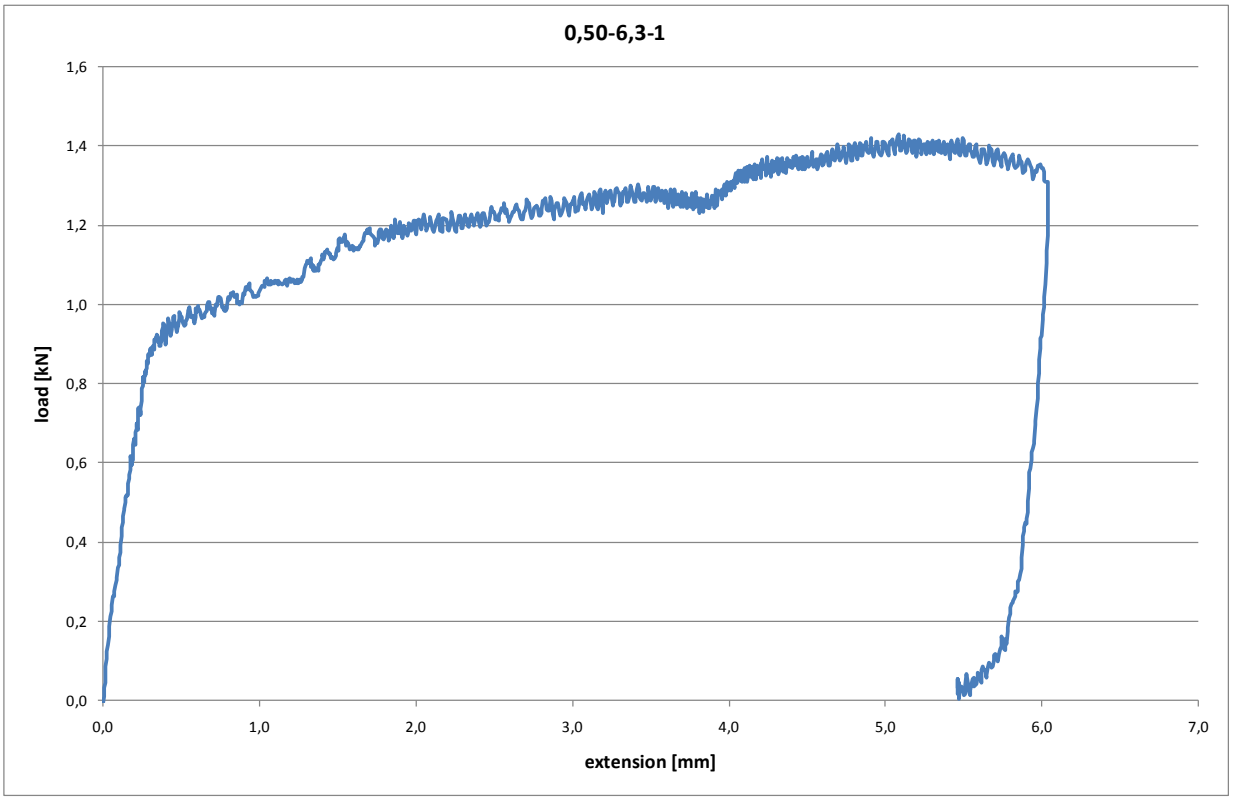
0,2
0,4
0,6
0,8
1,0
1,2
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

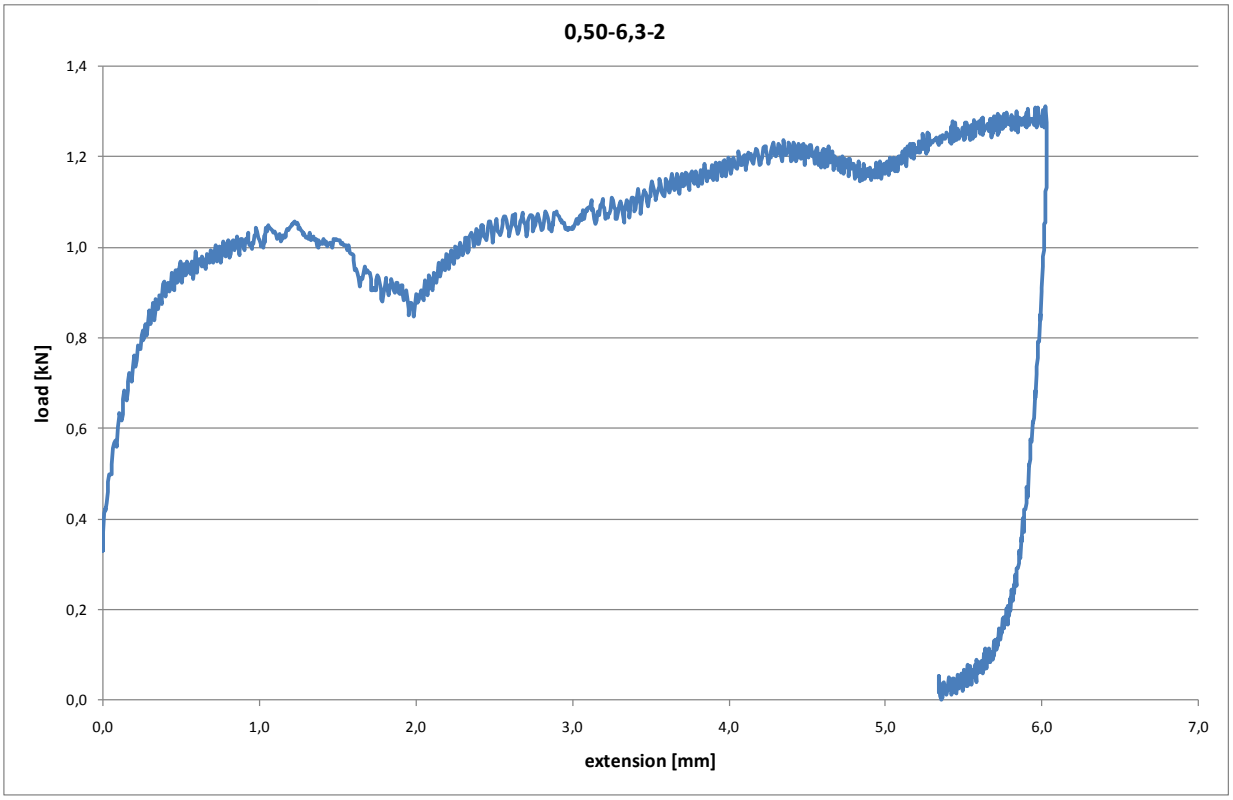
Test on connections of longitudinal joints

Thickness of face sheet: 0,50 mm

Nominal diameter of fastener: 6,3 mm

Connection without sealing tape

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load [kN]
extension [mm]
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0,2
0,4
0,6
0,8
1,0
1,2
1,4
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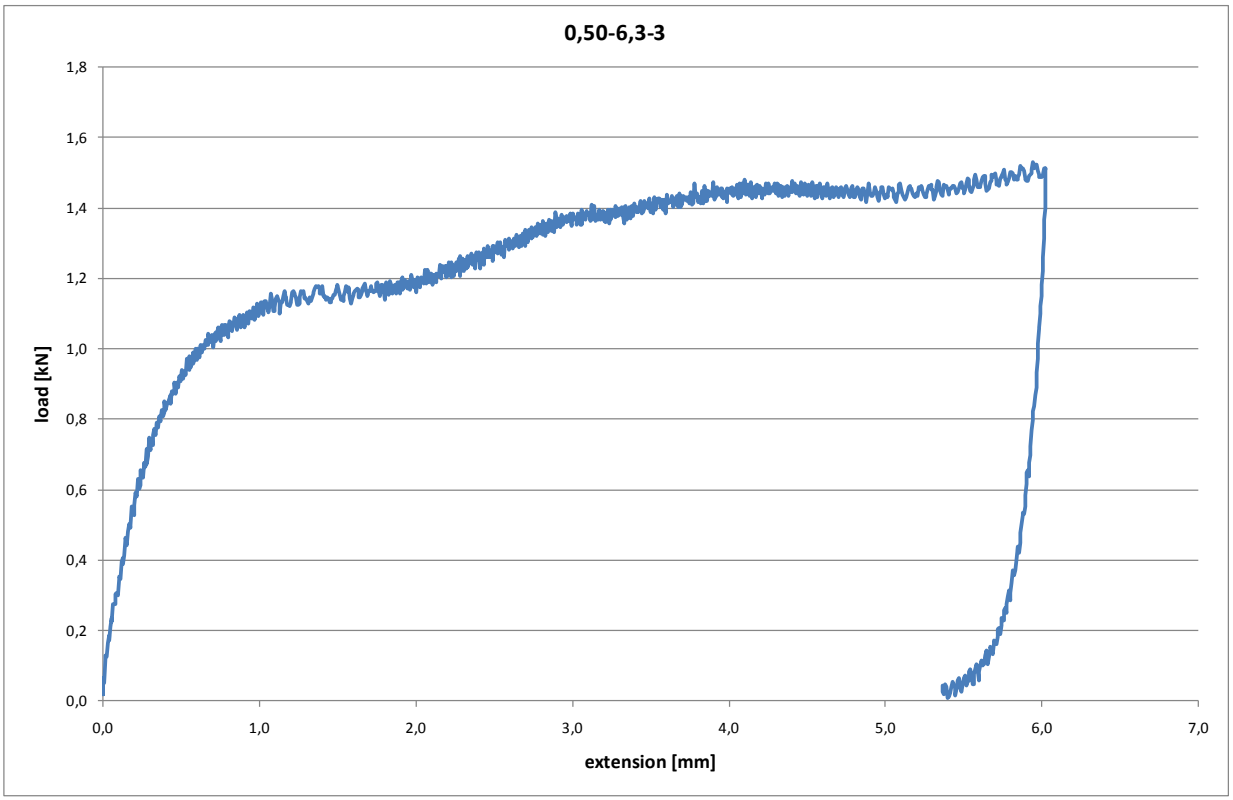
1,0
2,0
3,0
4,0
5,0
6,0
7,0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load [kN]
extension [mm]
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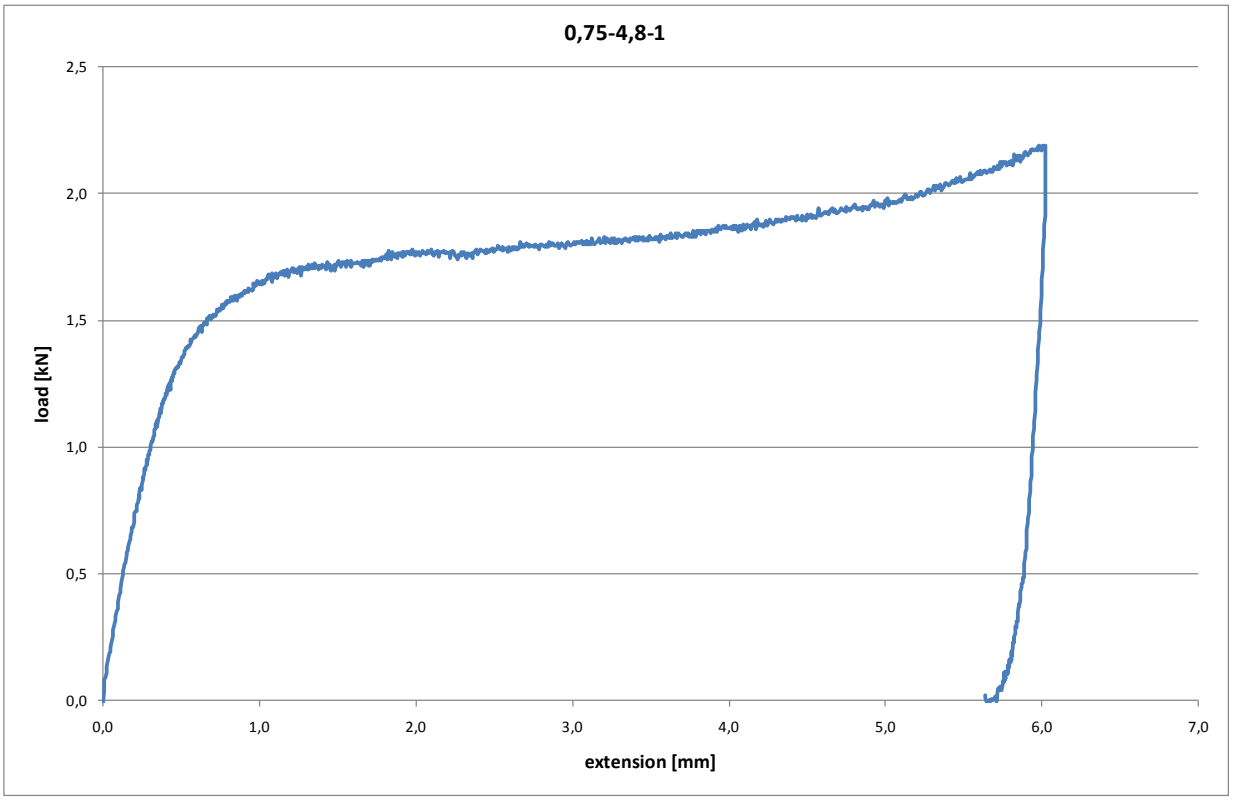
0,2
0,4
0,6
0,8
1,0
1,2
1,4
1,6
1,8
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

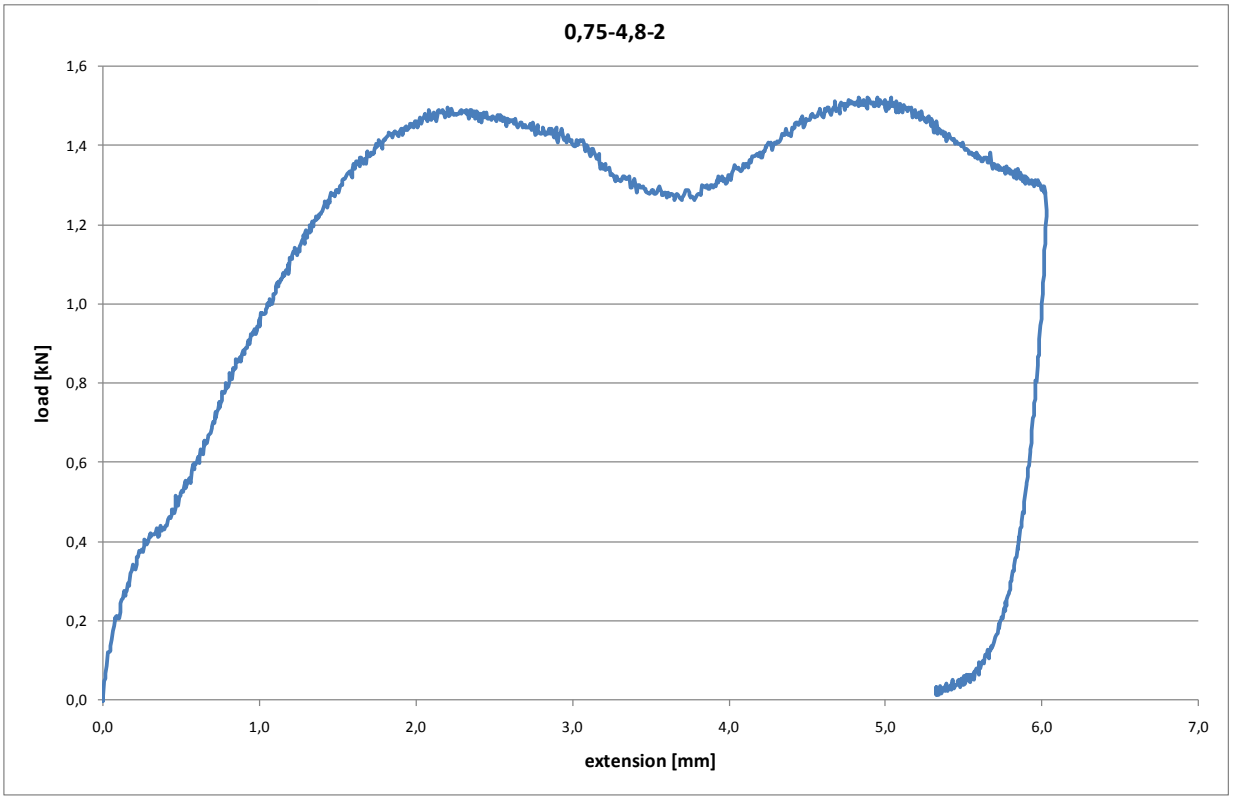
Test on connections of longitudinal joints

Thickness of face sheet: 0,75 mm

Nominal diameter of fastener: 4,8 mm

Connection without sealing tape

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load [kN]
extension [mm]
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0,2
0,4
0,6
0,8
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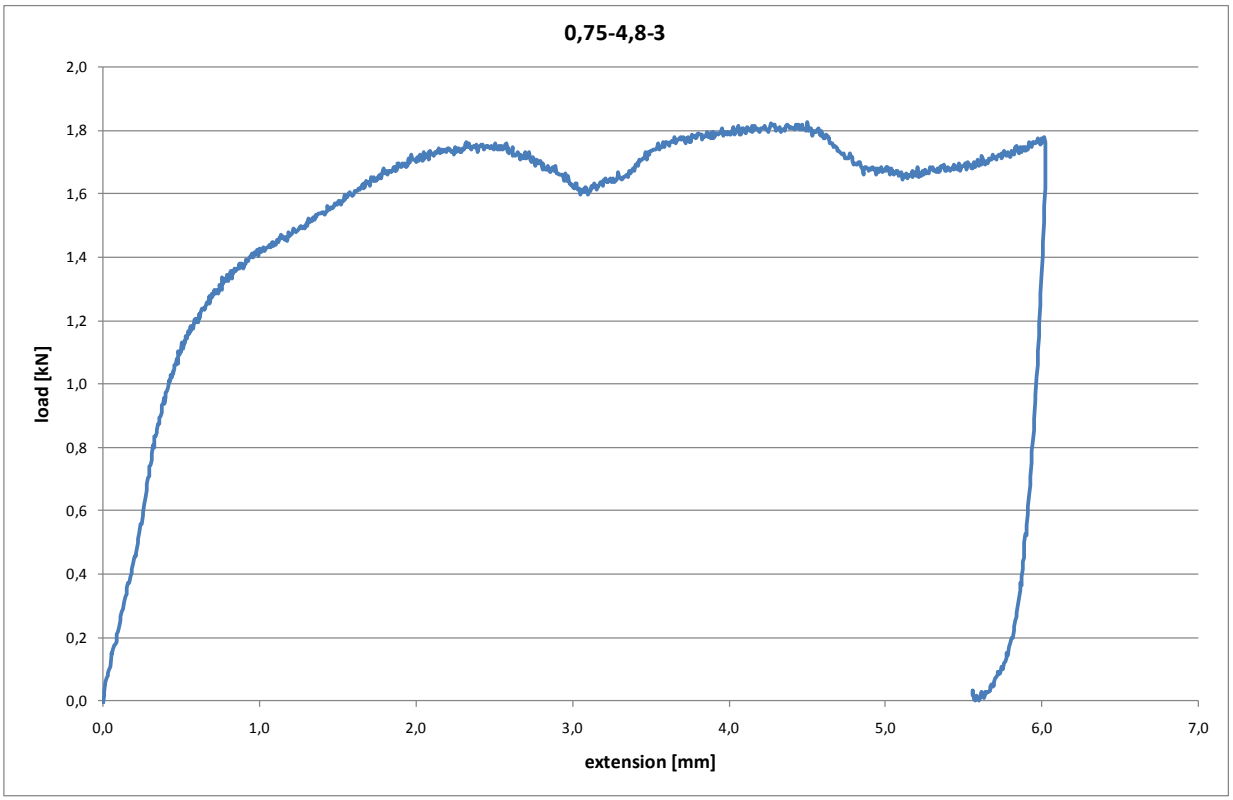
1,2
1,4
1,6
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0


0,75-4,8-3
load [kN]
extension [mm]
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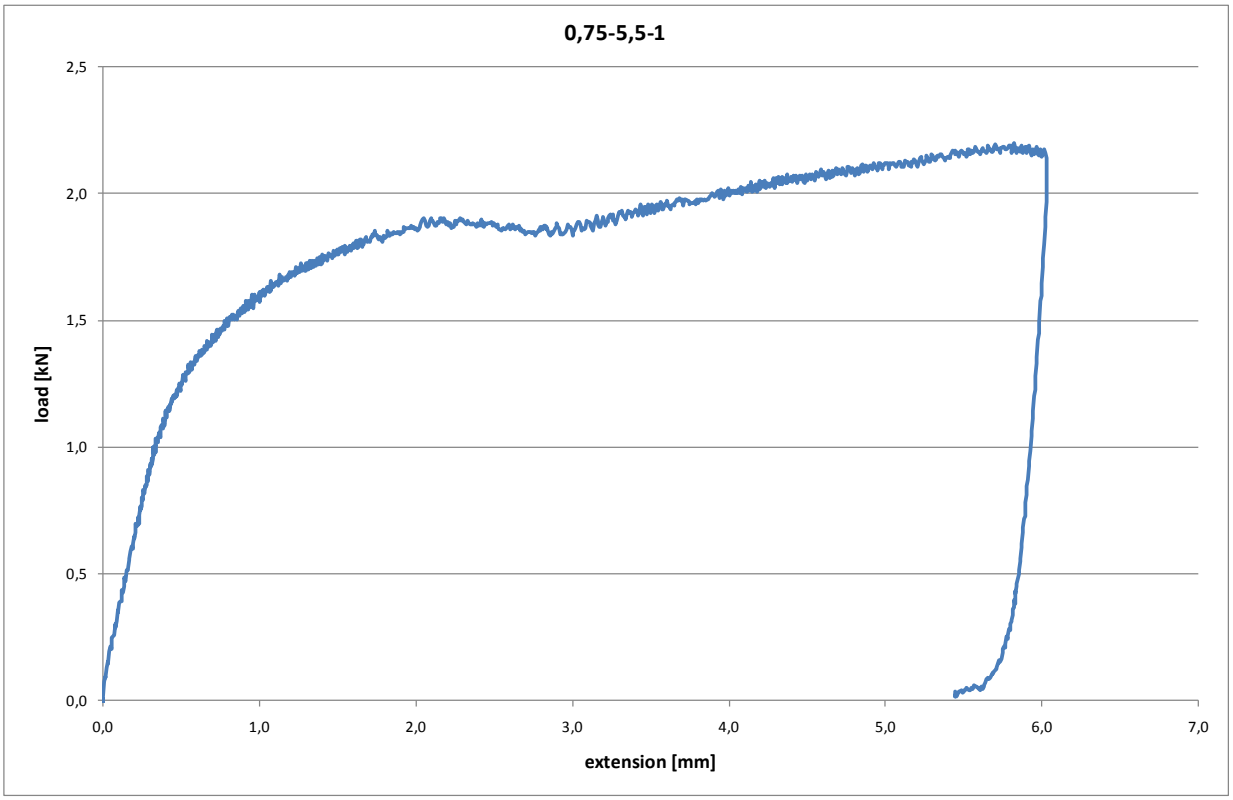
0,2
0,4
0,6
0,8
1,0
1,2
1,4
1,6
1,8
2,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

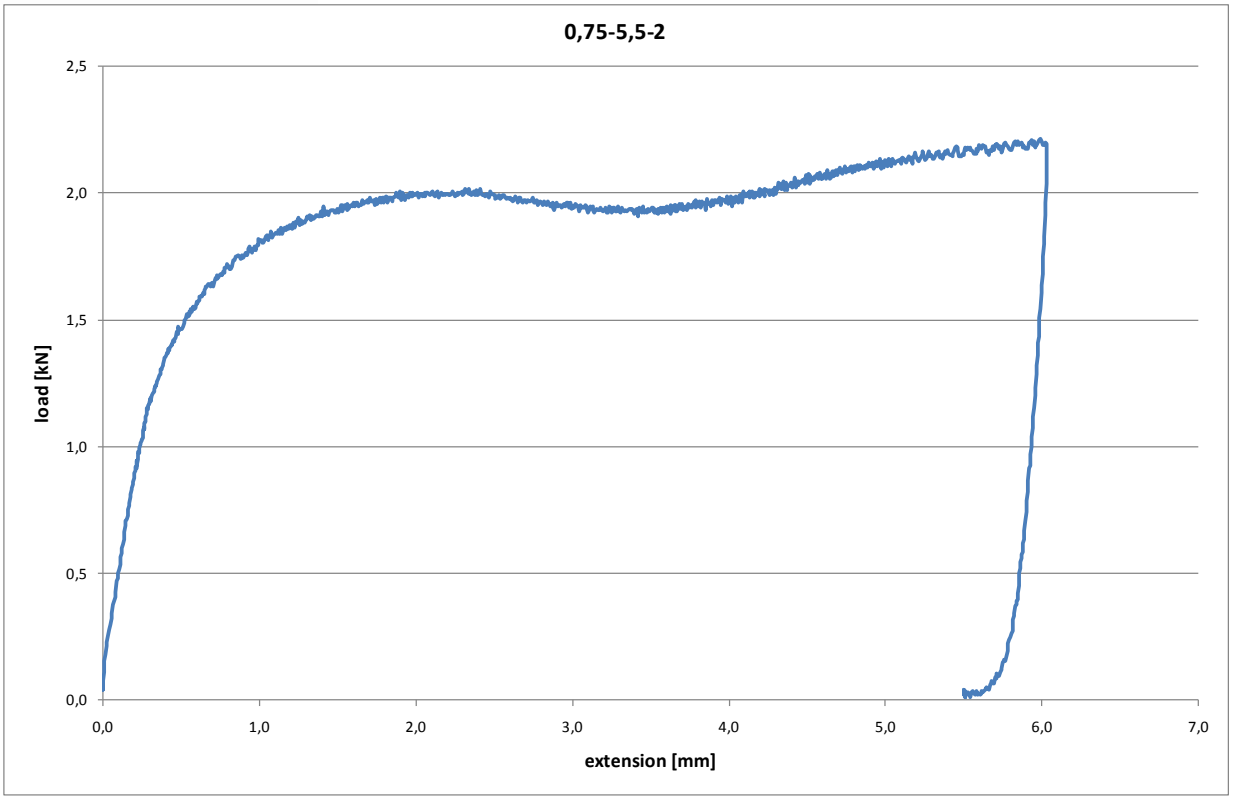
Test on connections of longitudinal joints

Thickness of face sheet: 0,75 mm

Nominal diameter of fastener: 5,5 mm

Connection without sealing tape

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extension [mm]
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1,5
2,0
2,5
0,0
1,0
2,0
3,0
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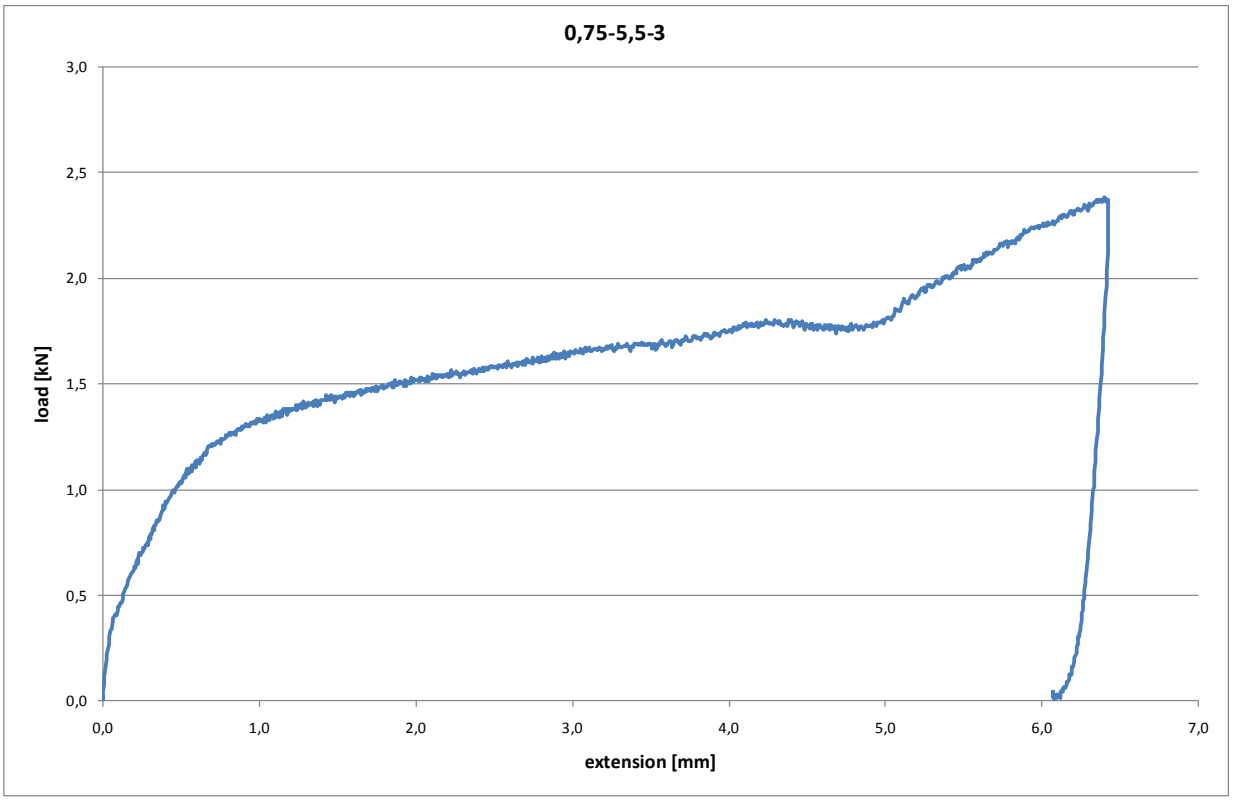
5,0
6,0
7,0


0,75-5,5-3
load [kN]
extension [mm]
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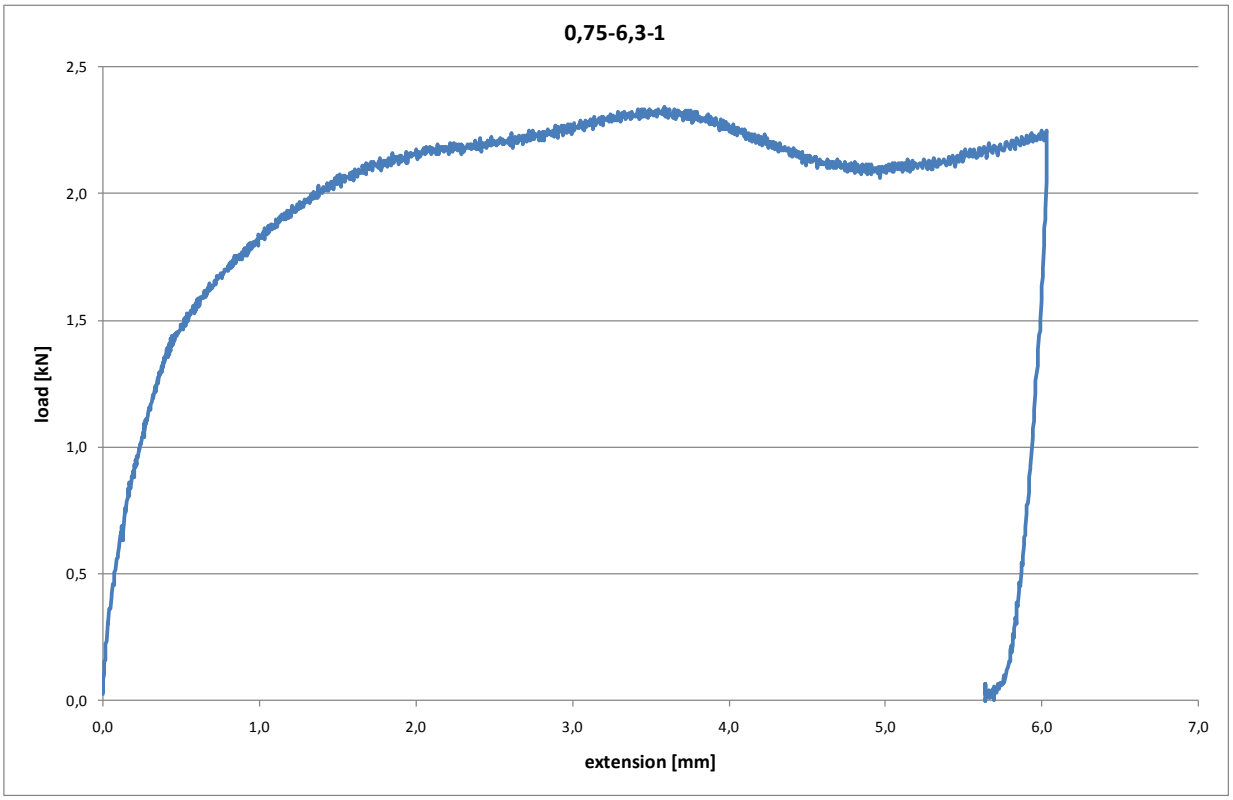
1,0
1,5
2,0
2,5
3,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

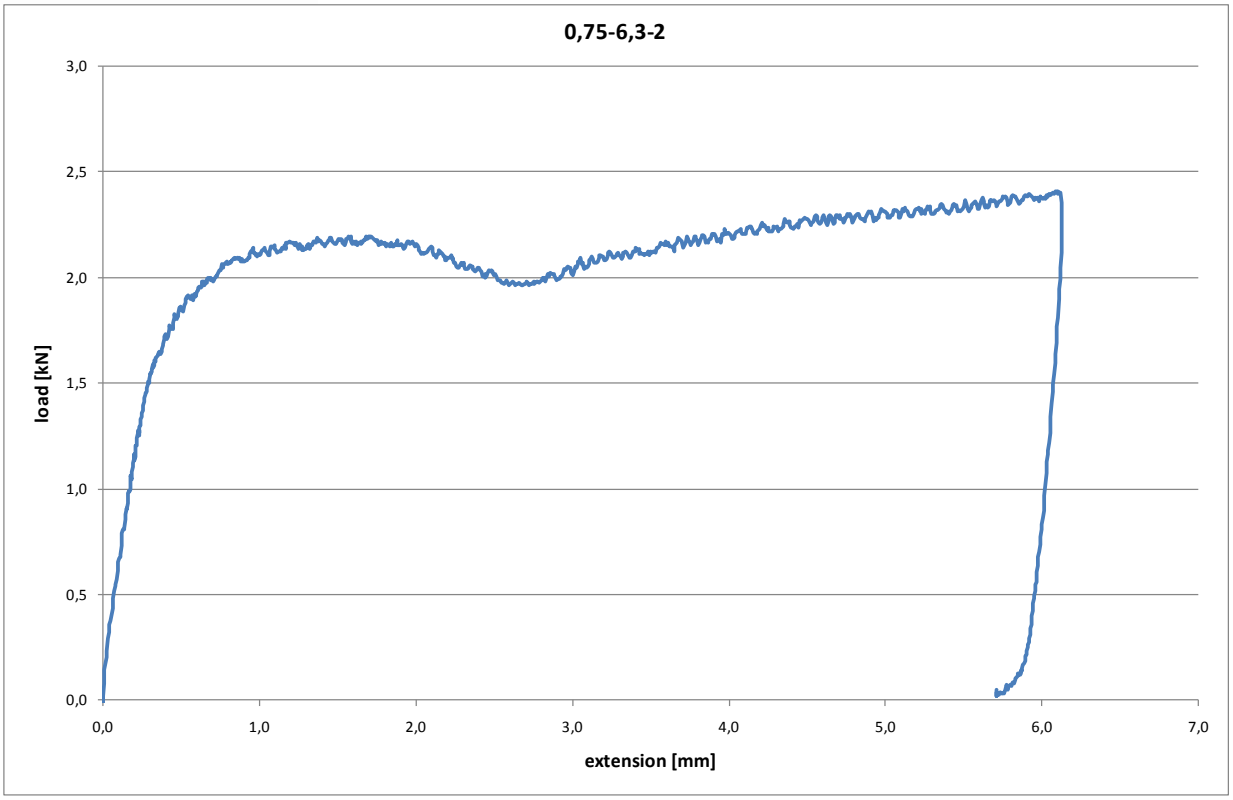
Test on connections of longitudinal joints

Thickness of face sheet: 0,75 mm

Nominal diameter of fastener: 6,3 mm

Connection without sealing tape

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load [kN]
extension [mm]
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2,5
2,0
1,5
1,0
0,5
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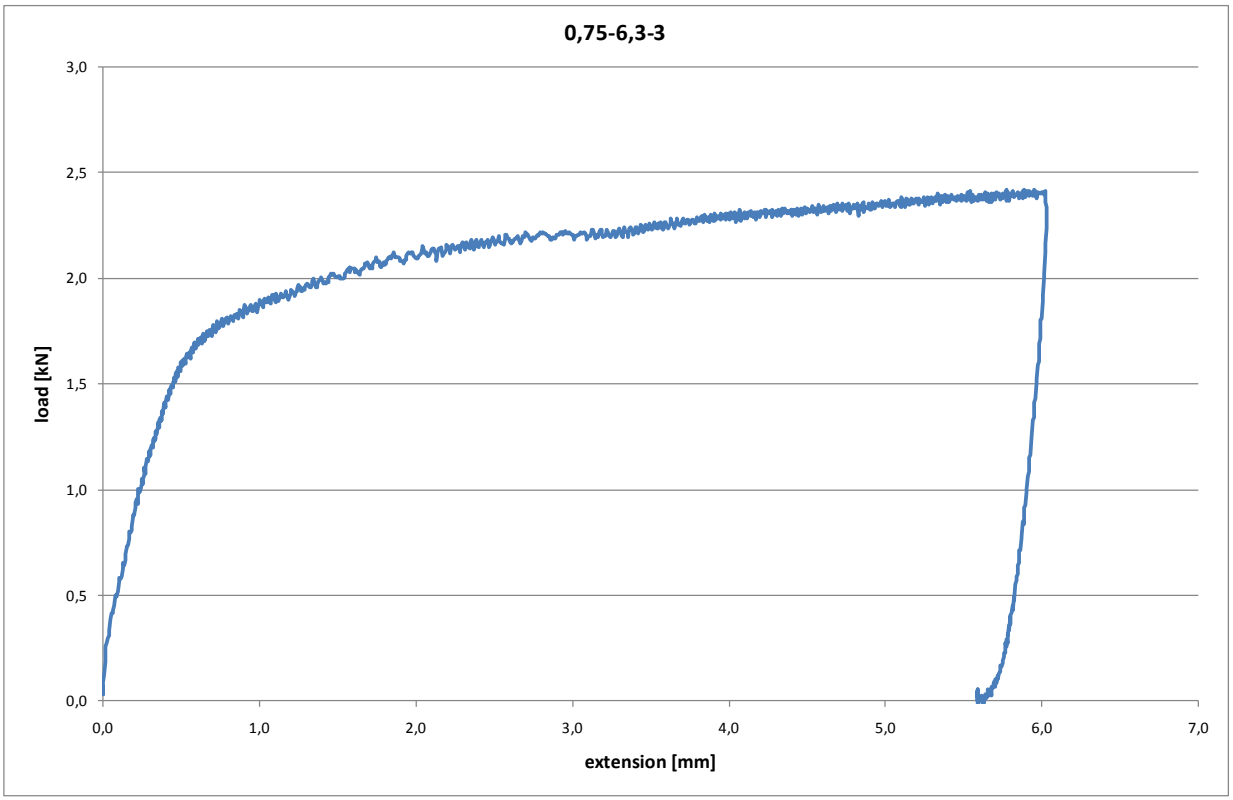
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0


0,75-6,3-3
load [kN]
extension [mm]
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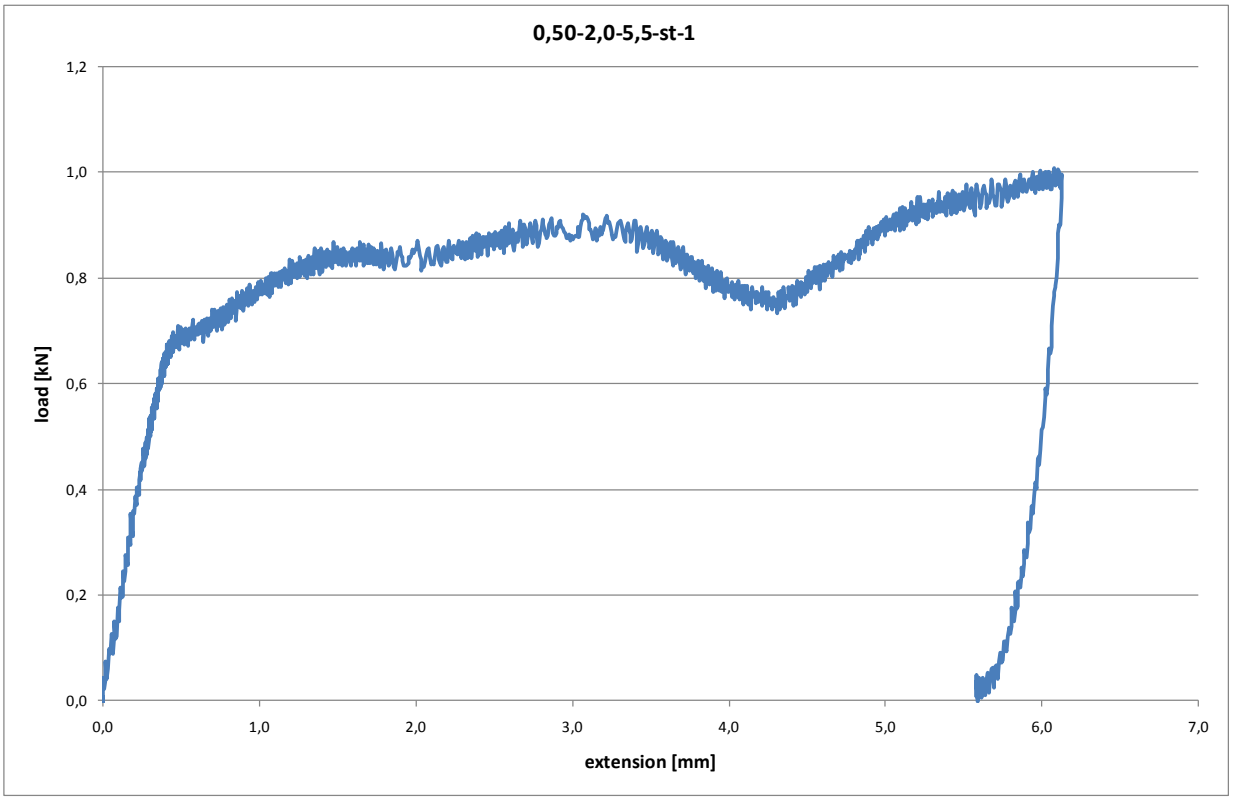
2,5
2,0
1,5
1,0
0,5
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

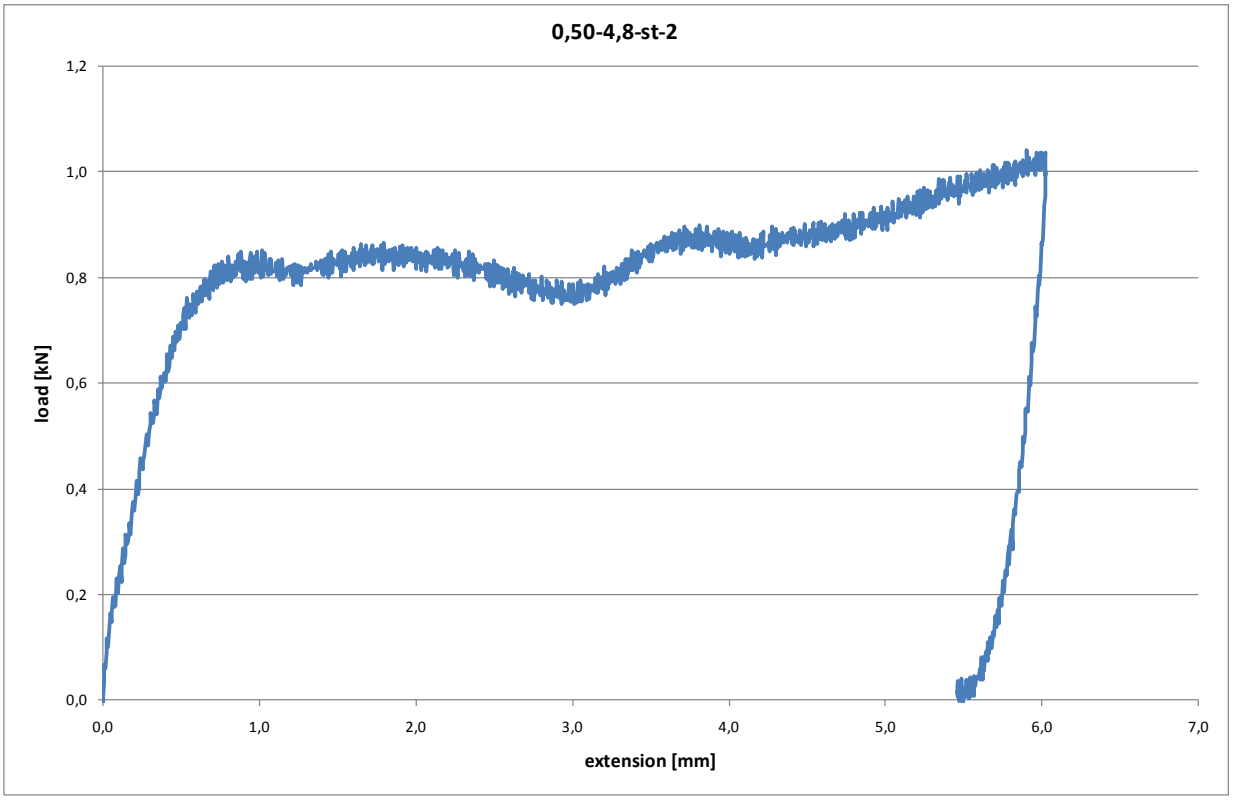
Test on connections of longitudinal joints

Thickness of face sheet: 0,50 mm

Nominal diameter of fastener: 4,8 mm

Connection with sealing tape




0,50-4,8-st-2
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extension [mm]
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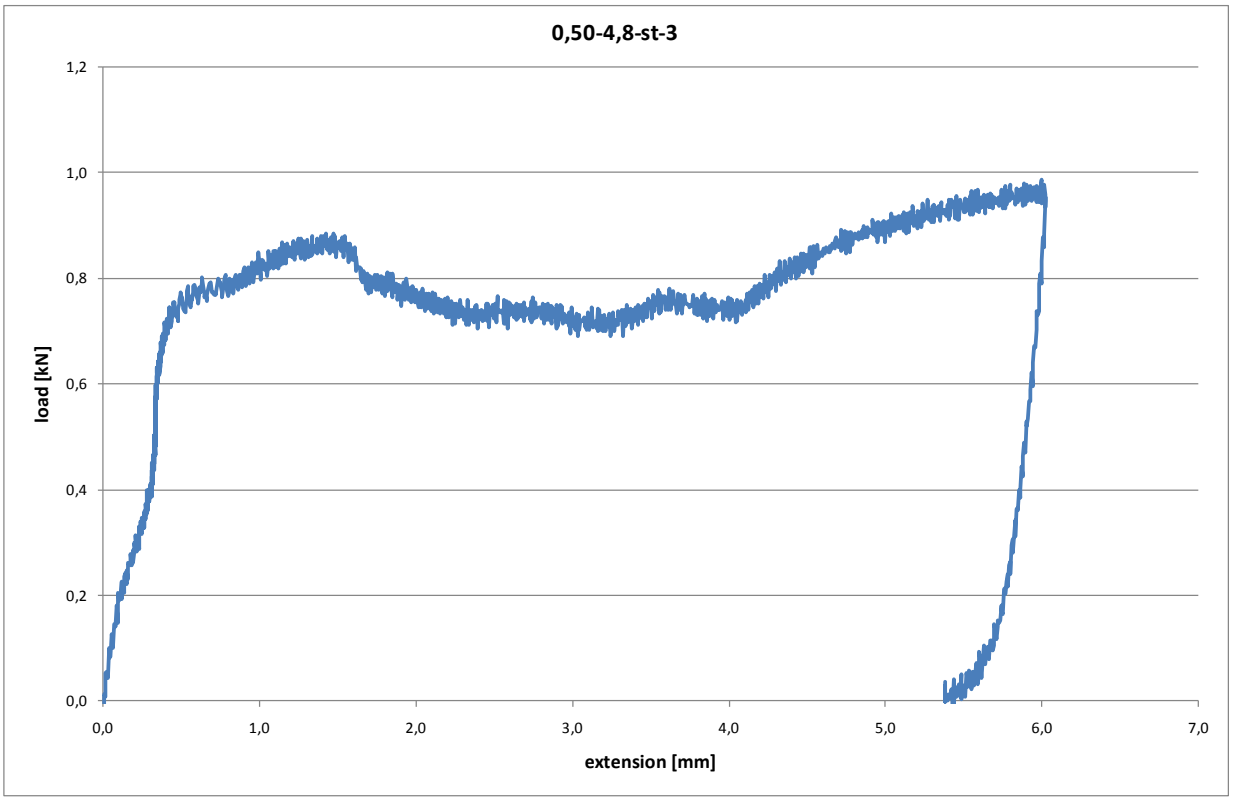
0,4
0,6
0,8
1,0
1,2
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

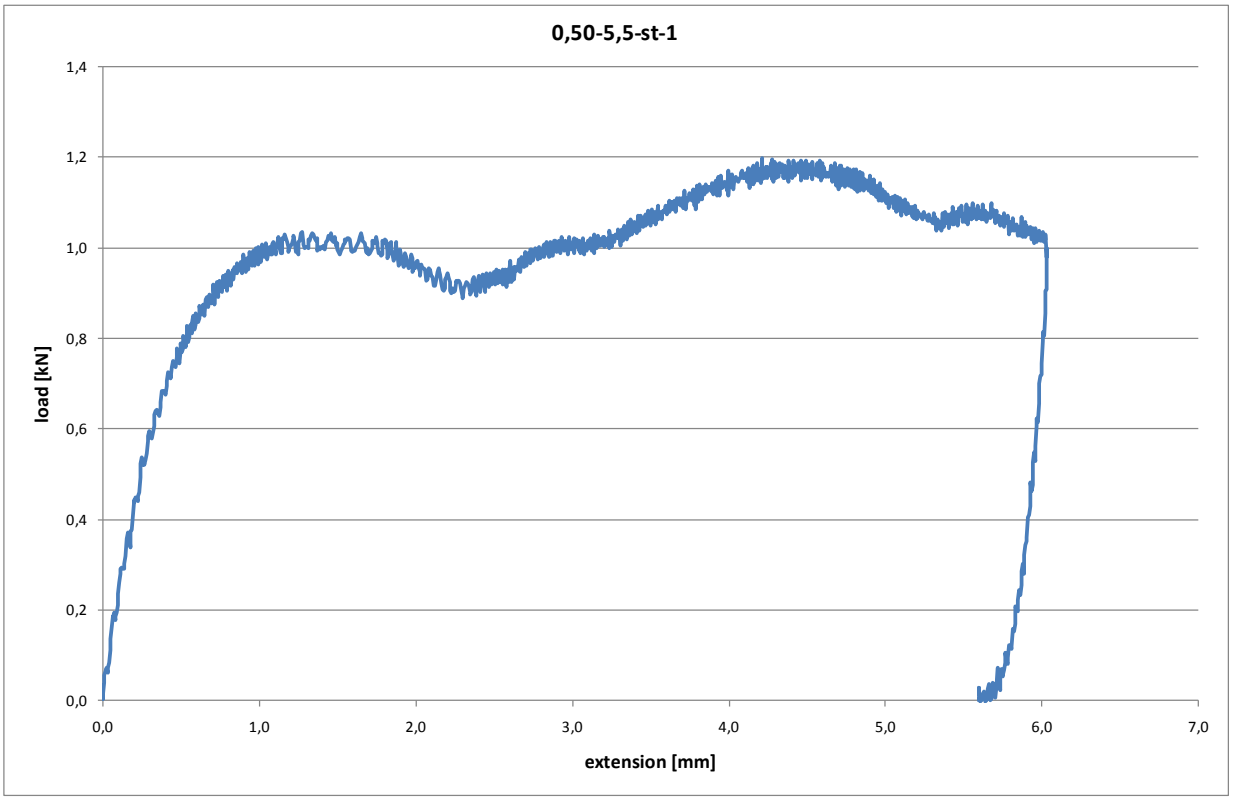

0,50-4,8-st-3
load [kN]
extension [mm]
0,0
0,2
0,4
0,6
0,8
1,0
1,2
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

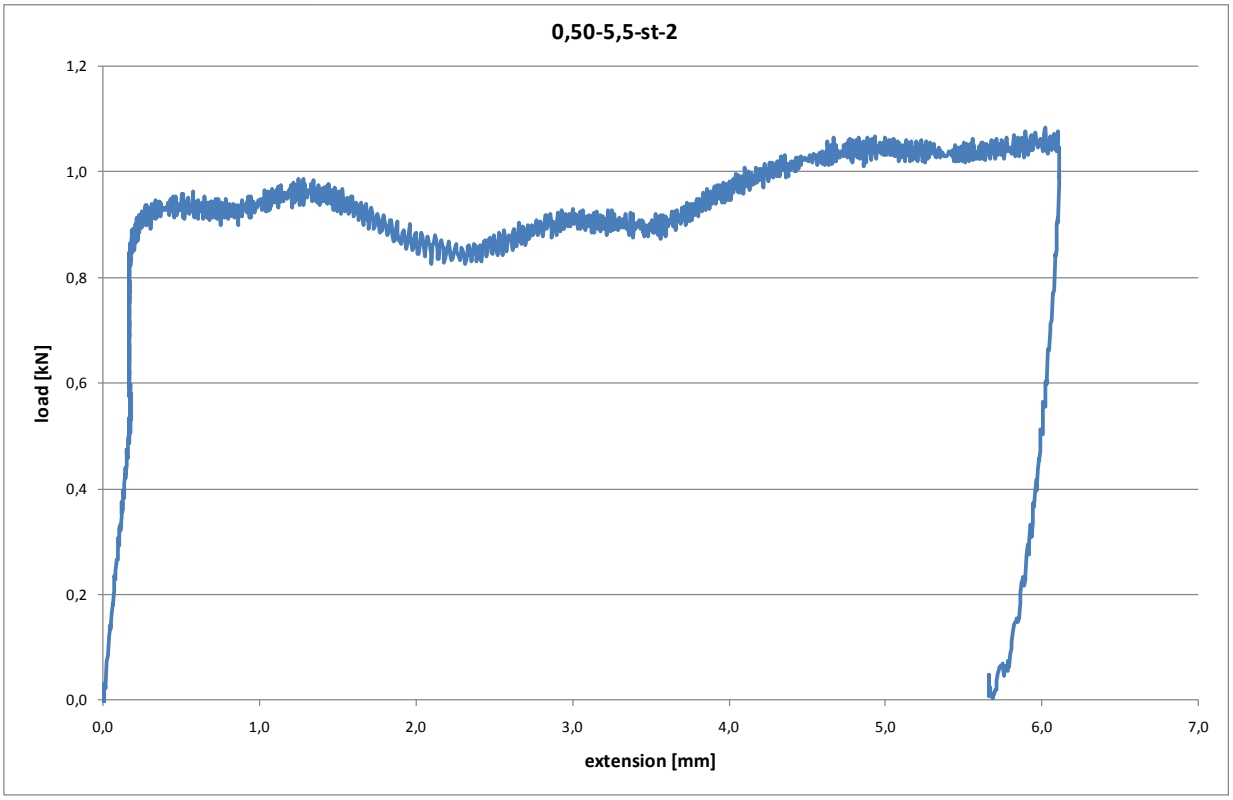
Test on connections of longitudinal joints

Thickness of face sheet: 0,50 mm

Nominal diameter of fastener: 5,5 mm

Connection with sealing tape

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0,2
0,4
0,6
0,8
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1,2
0,0
1,0
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3,0
4,0
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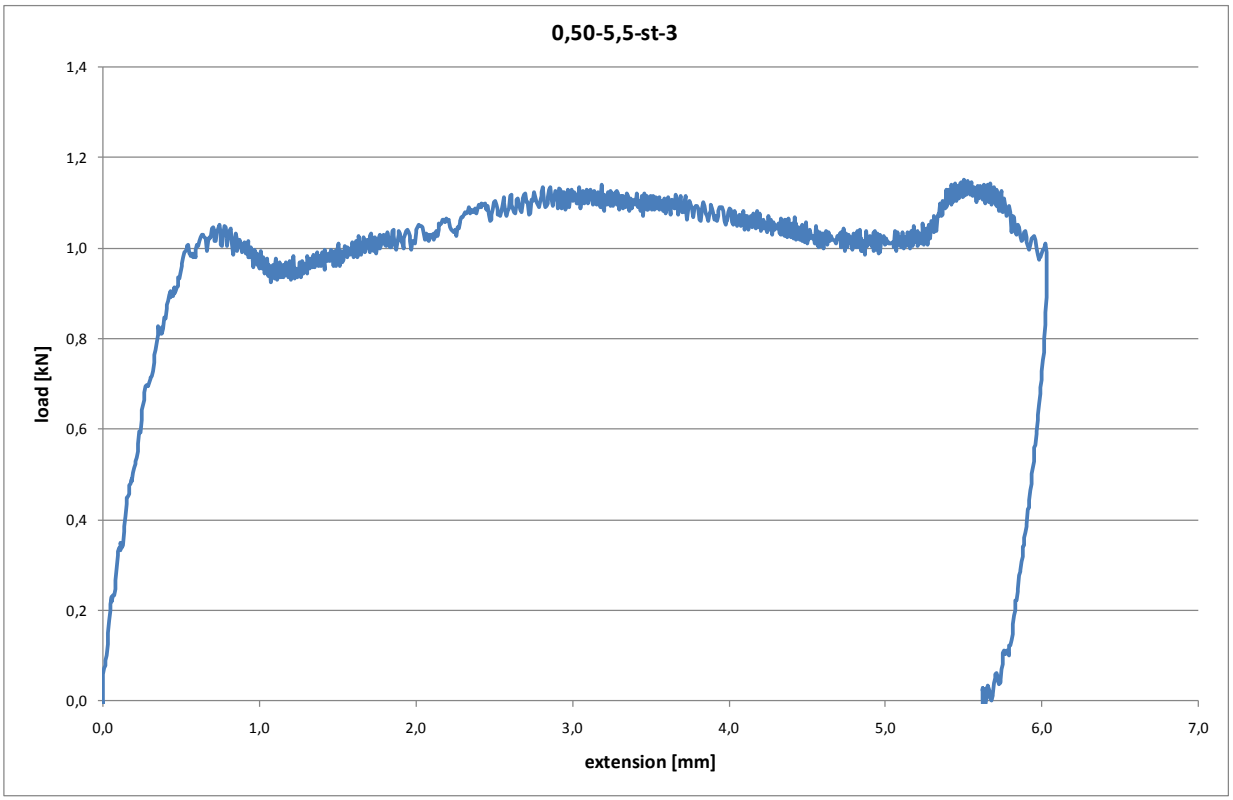
6,0
7,0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load [kN]
extension [mm]
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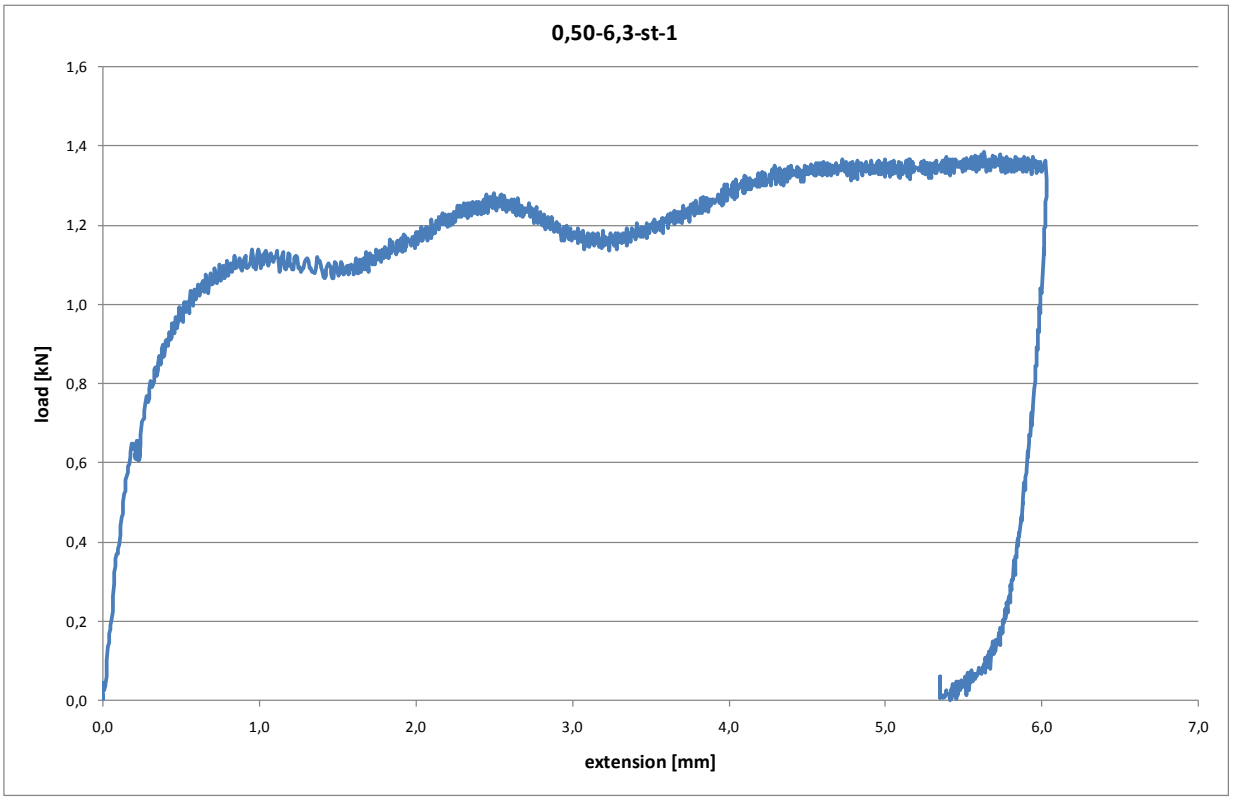
0,2
0,4
0,6
0,8
1,0
1,2
1,4
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

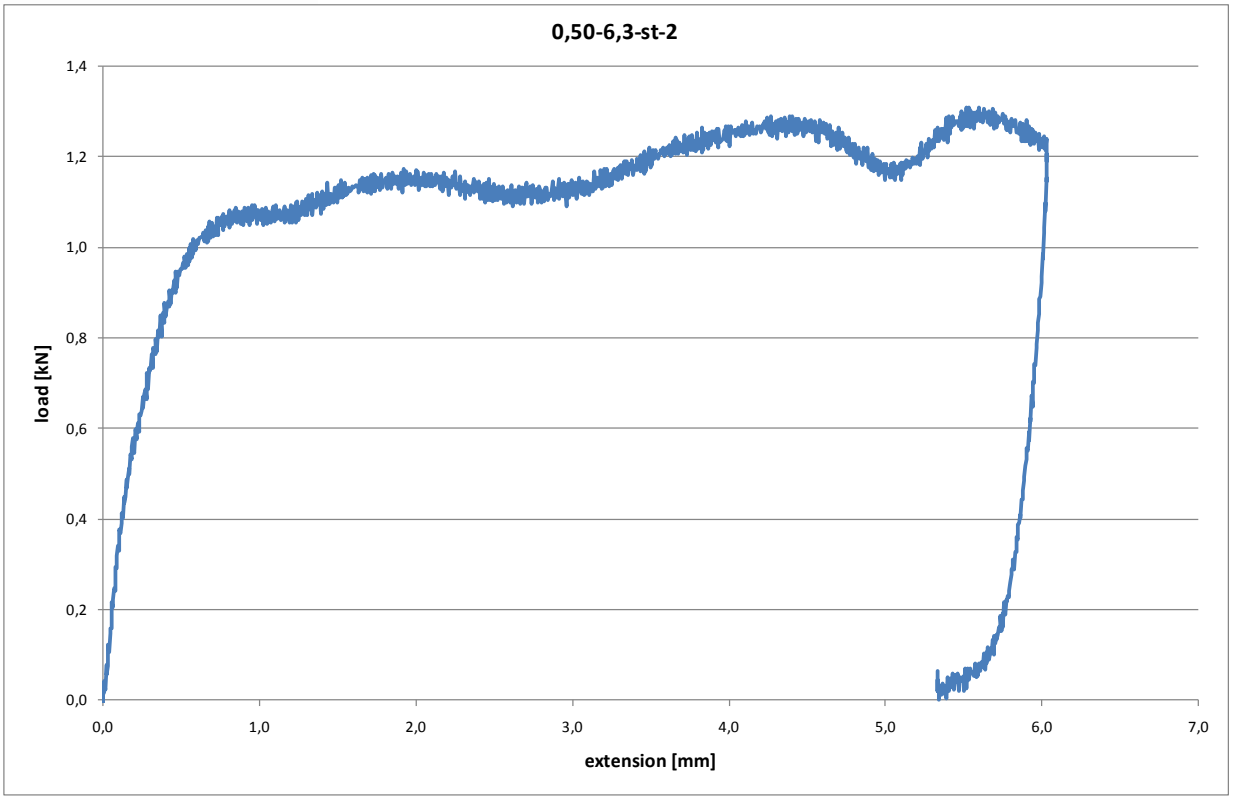
Test on connections of longitudinal joints

Thickness of face sheet: 0,50 mm

Nominal diameter of fastener: 6,3 mm

Connection with sealing tape

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0,2
0,4
0,6
0,8
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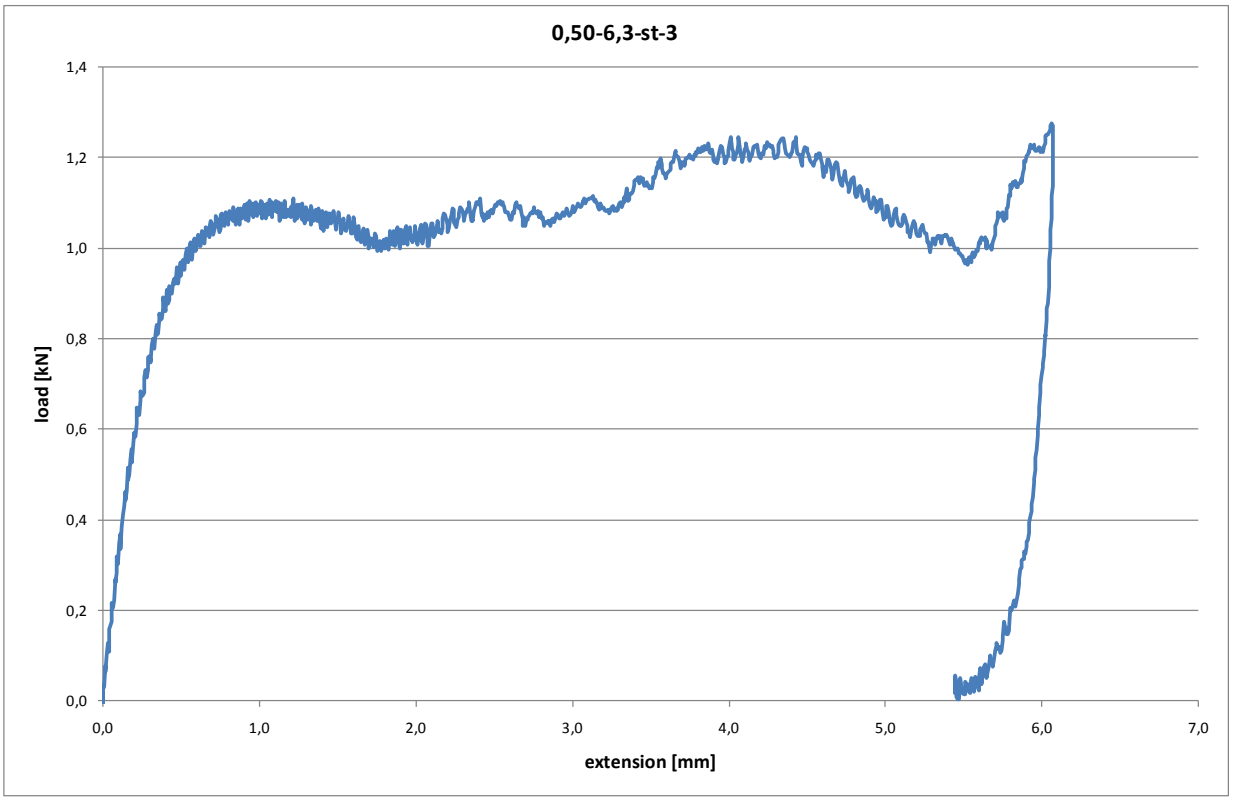
1,2
1,4
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0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load [kN]
extension [mm]
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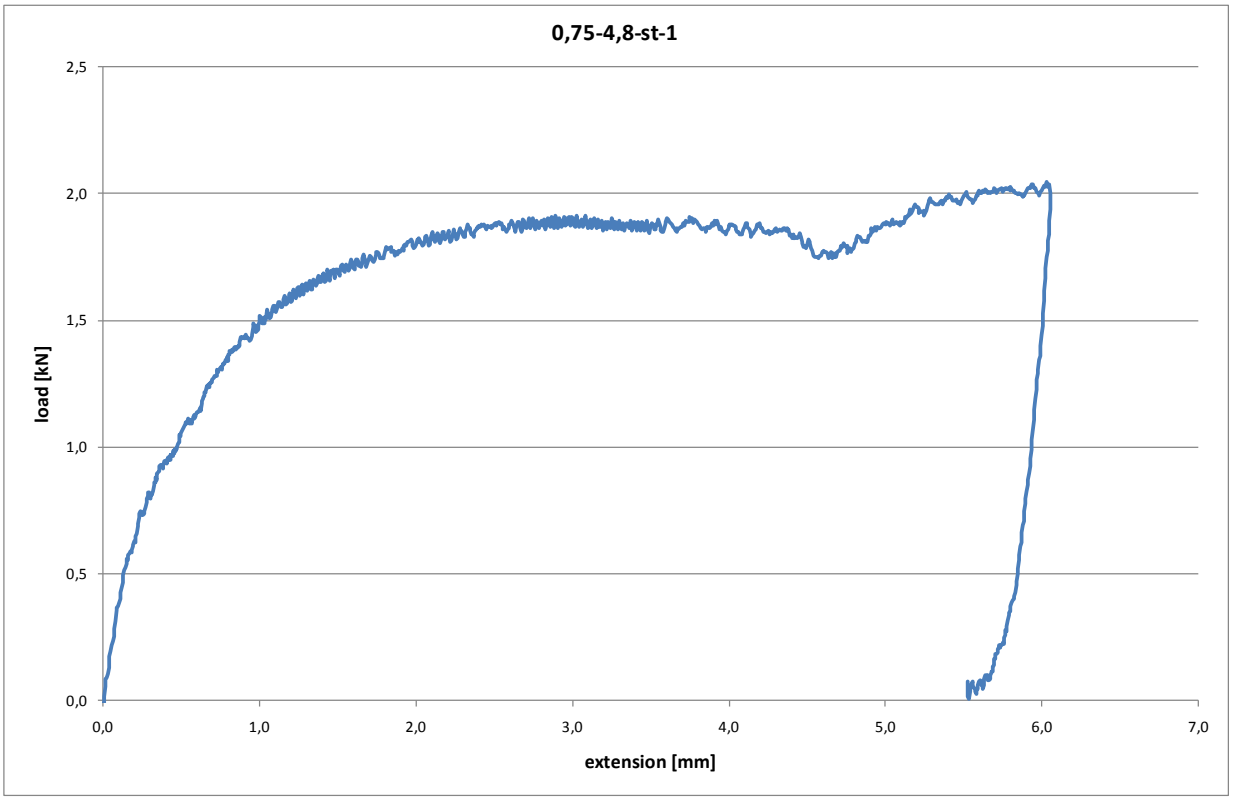
0,2
0,4
0,6
0,8
1,0
1,2
1,4
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

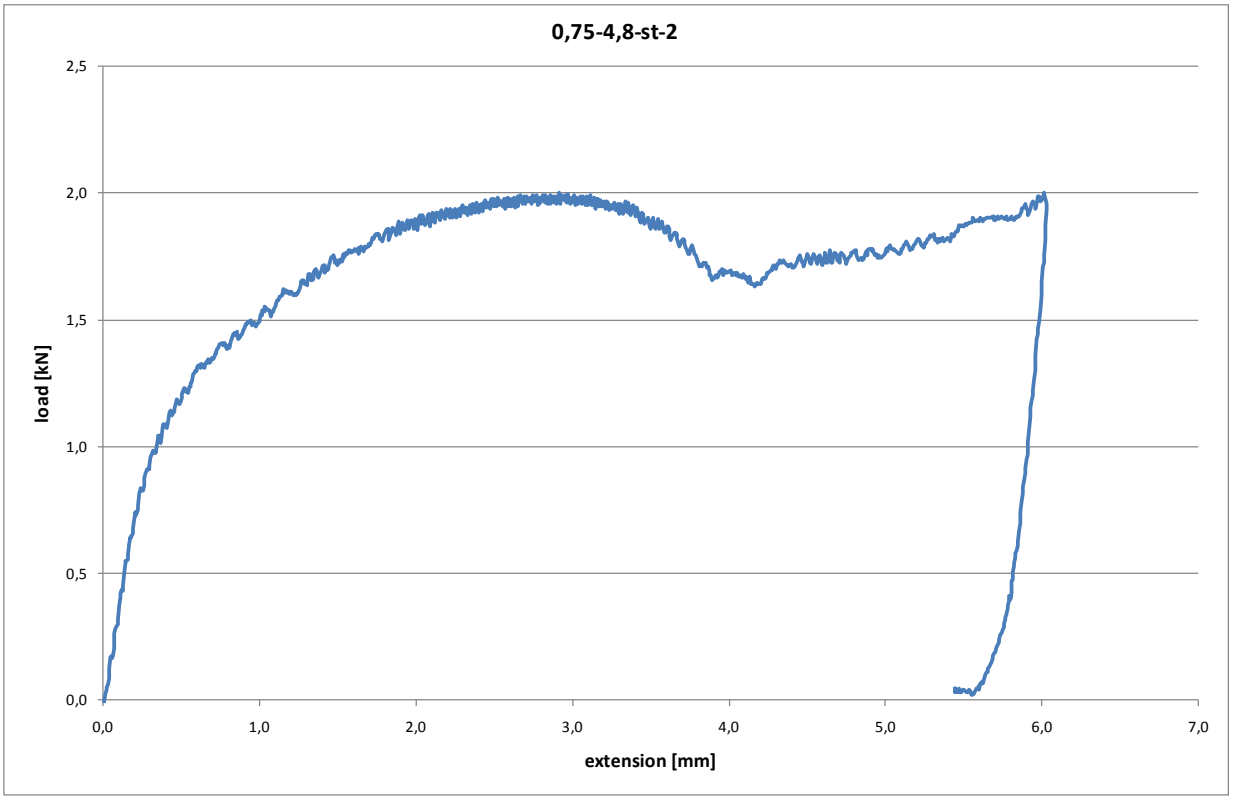
Test on connections of longitudinal joints

Thickness of face sheet: 0,75 mm

Nominal diameter of fastener: 4,8 mm

Connection with sealing tape

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1,5
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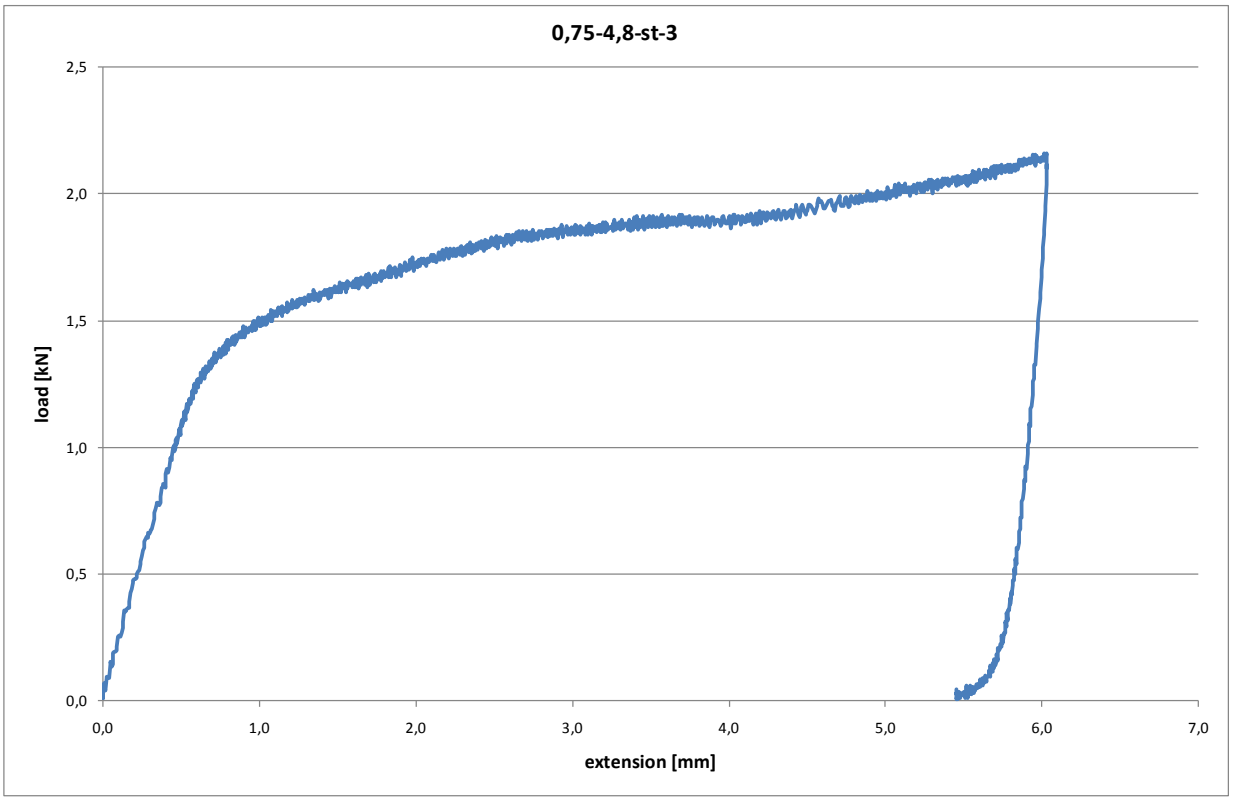
6,0
7,0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load [kN]
extension [mm]
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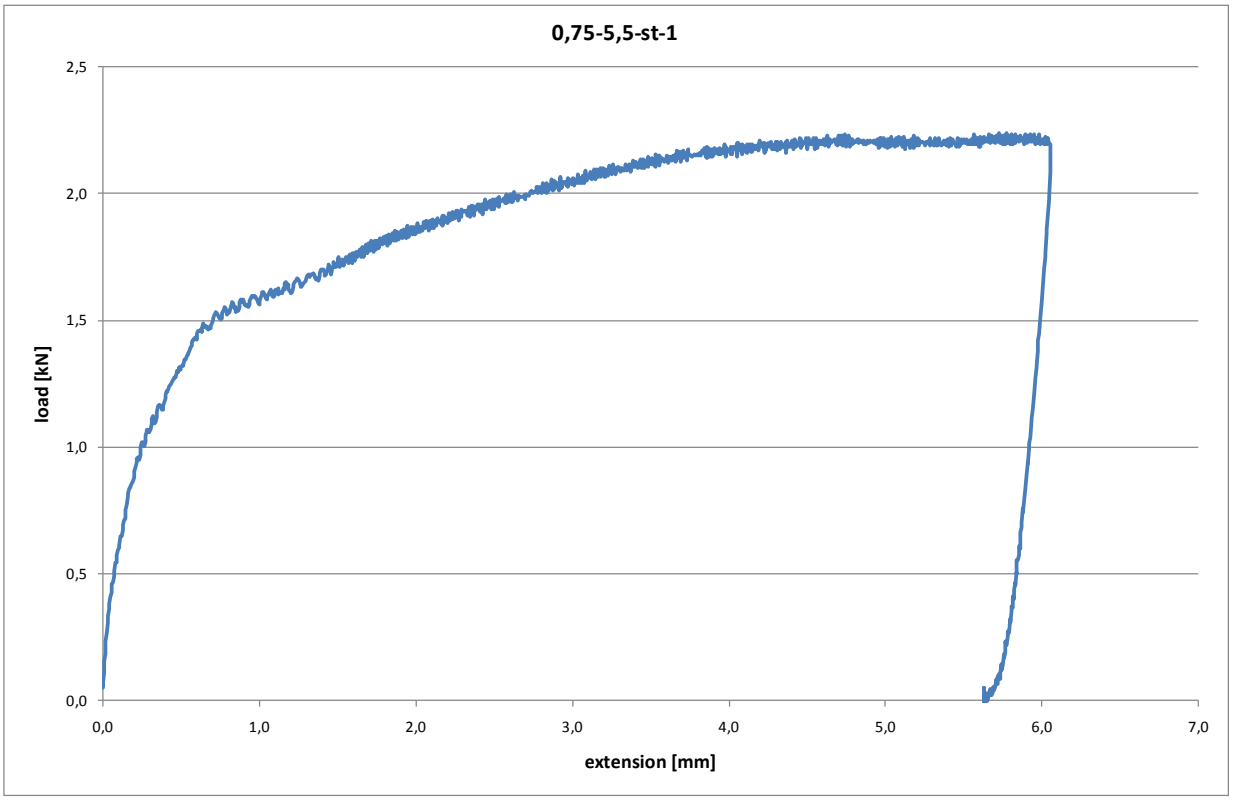
2,0
1,5
1,0
0,5
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

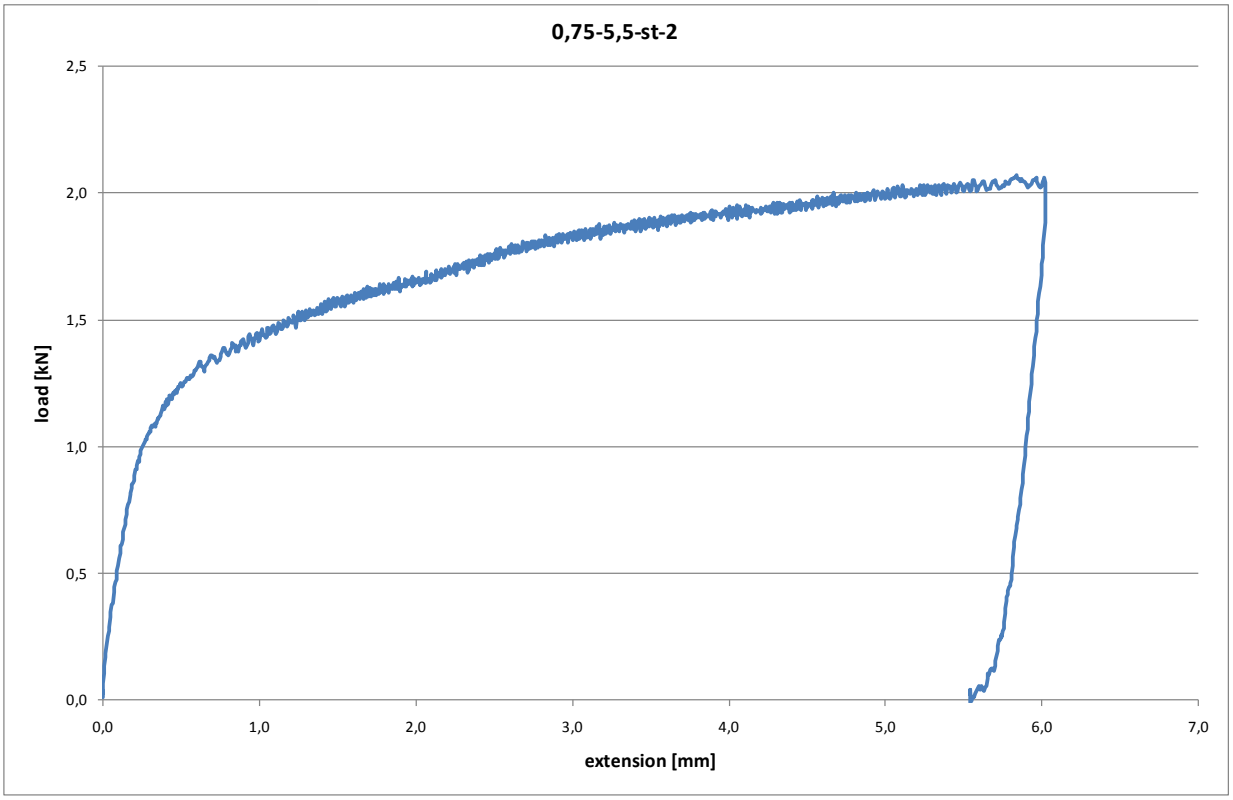
Test on connections of longitudinal joints

Thickness of face sheet: 0,75 mm

Nominal diameter of fastener: 5,5 mm

Connection with sealing tape

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1,5
1,0
0,5
0,0
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1,0
2,0
3,0
4,0
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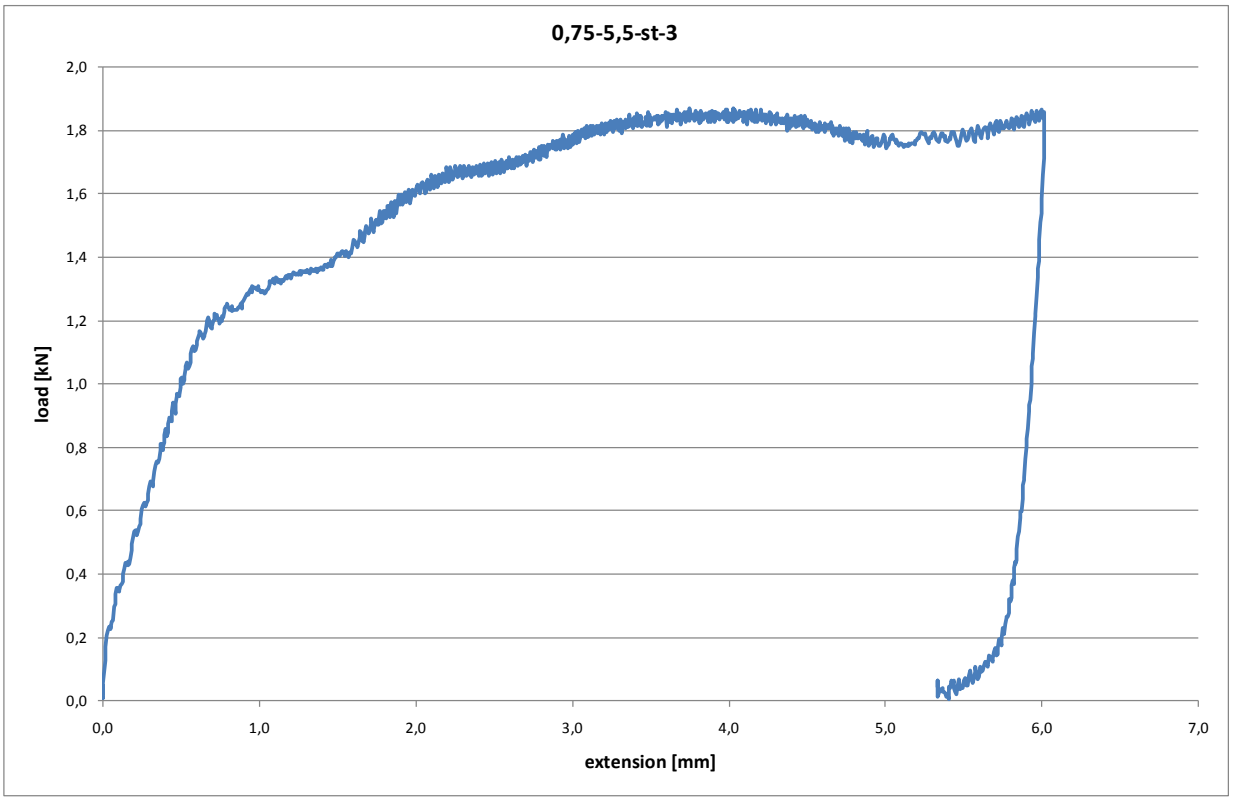
6,0
7,0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extension [mm]
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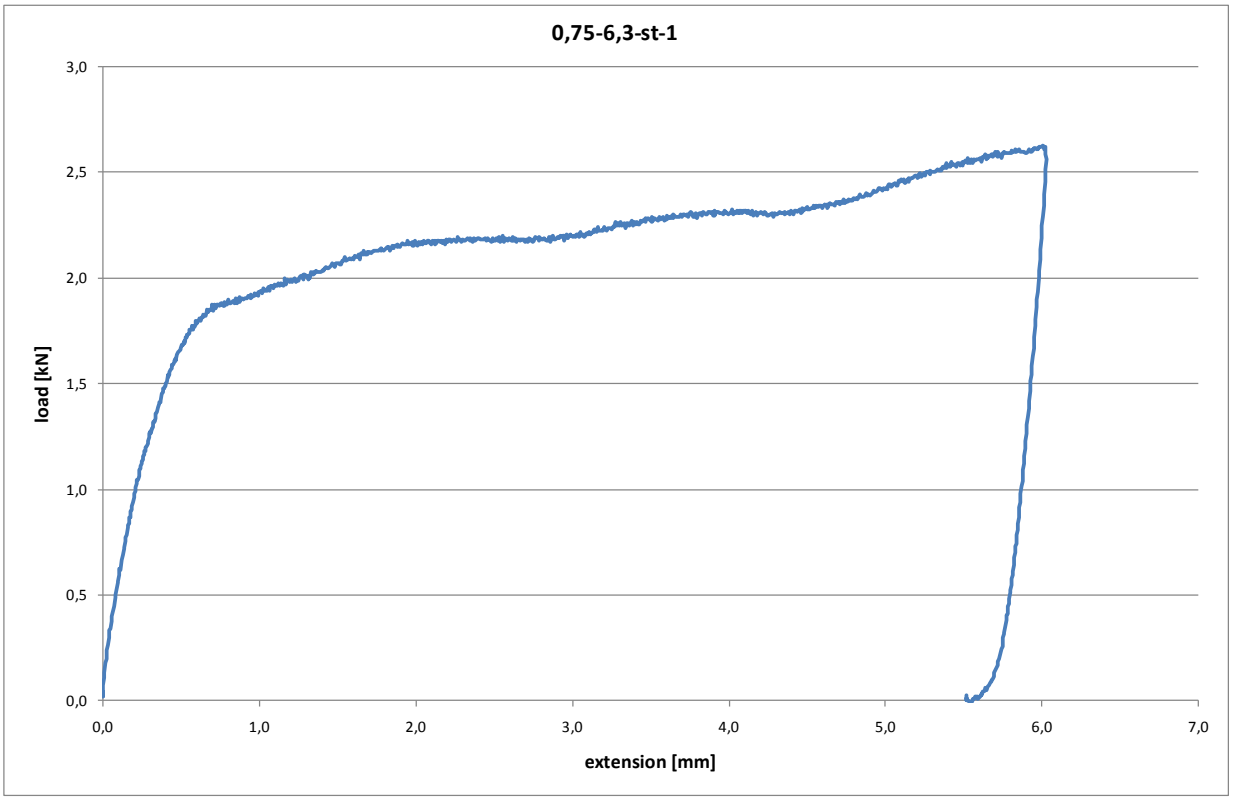
1,6
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

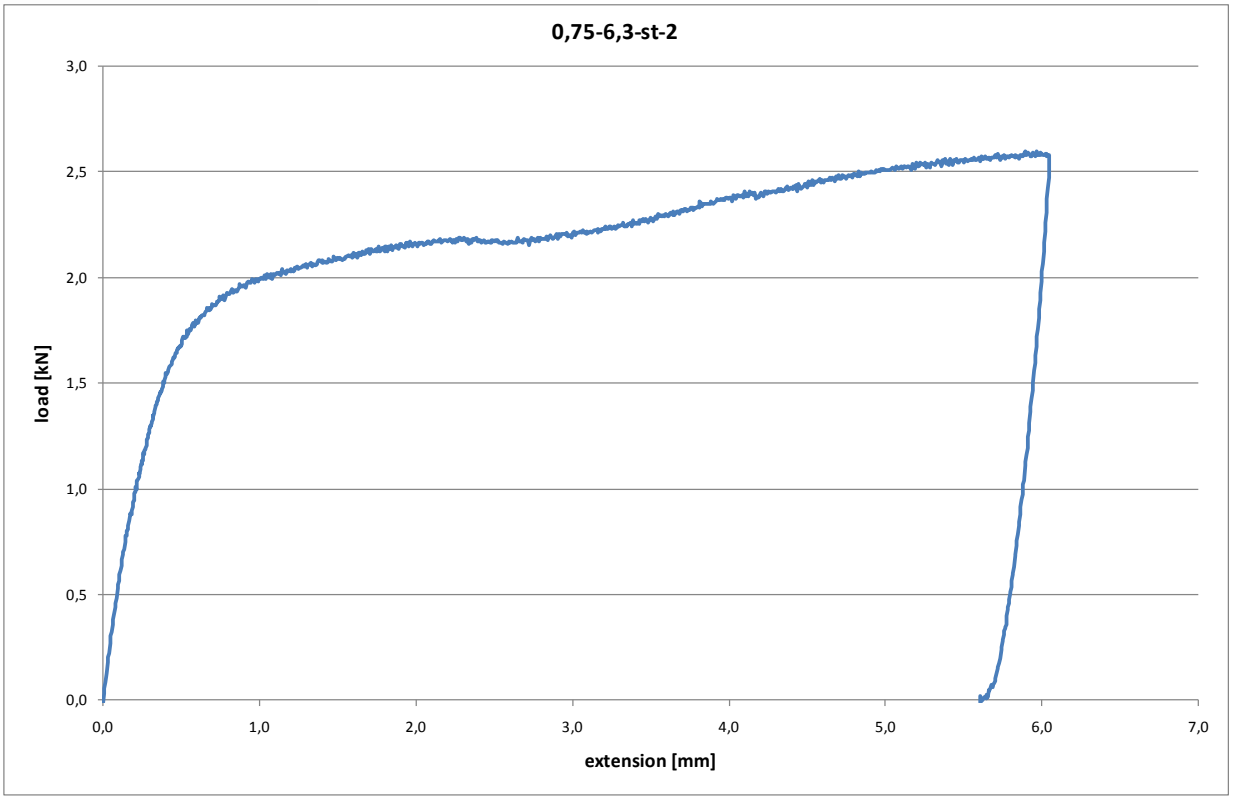
Test on connections of longitudinal joints

Thickness of face sheet: 0,75 mm

Nominal diameter of fastener: 6,3 mm

Connection with sealing tape

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load [kN]
extension [mm]
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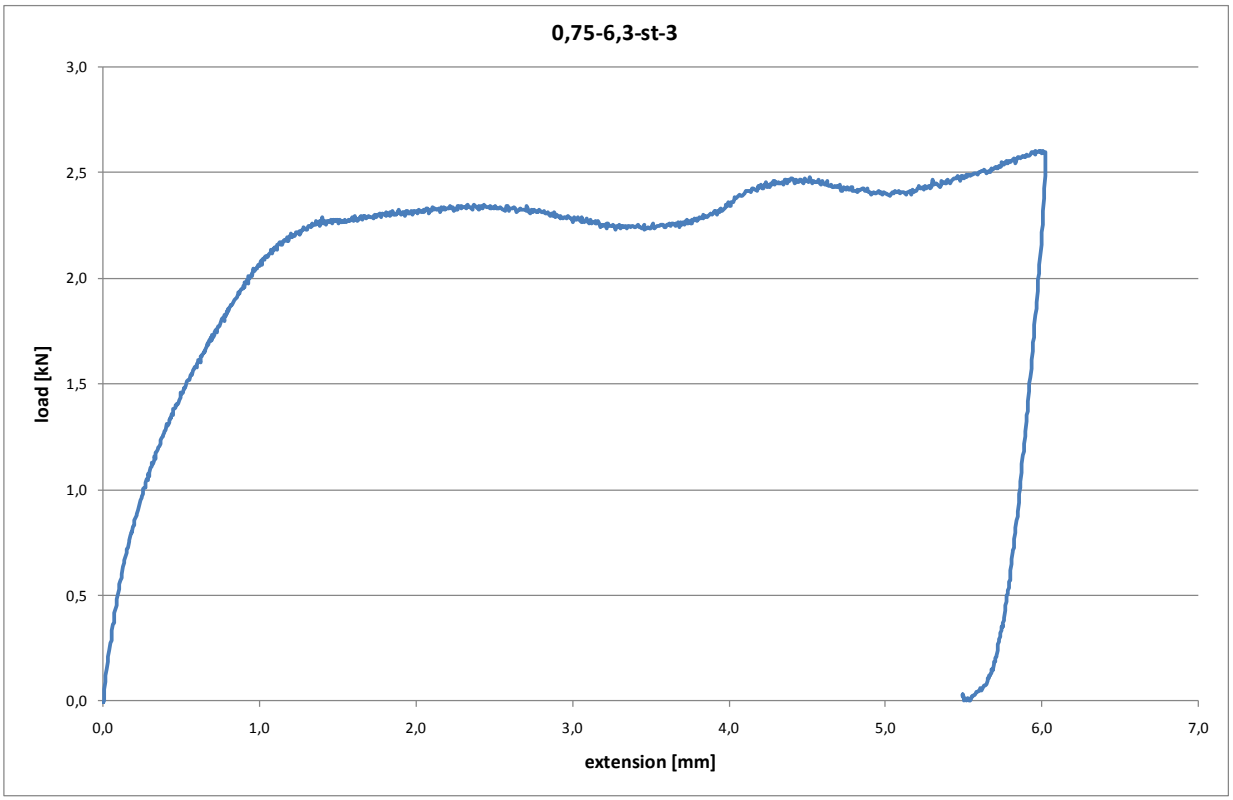
2,5
2,0
1,5
1,0
0,5
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

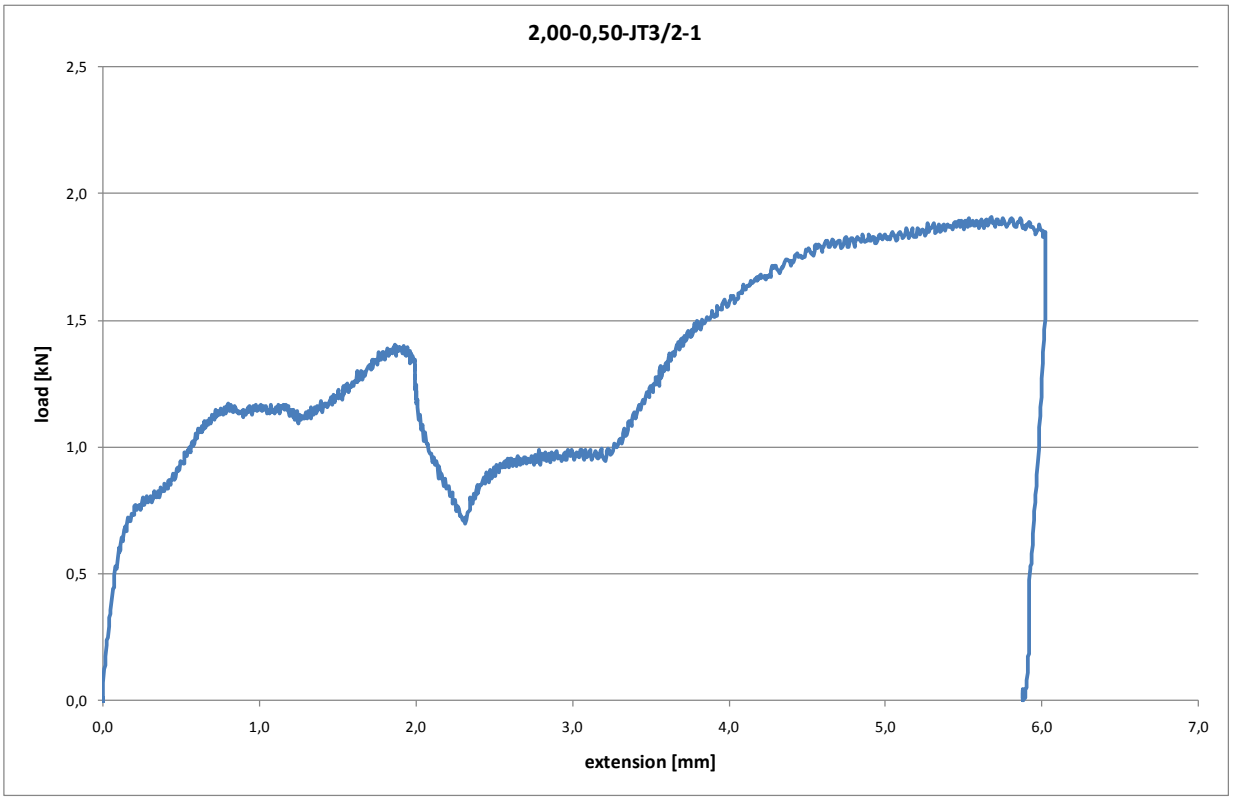

0,75-6,3-st-3
load [kN]
extension [mm]
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0

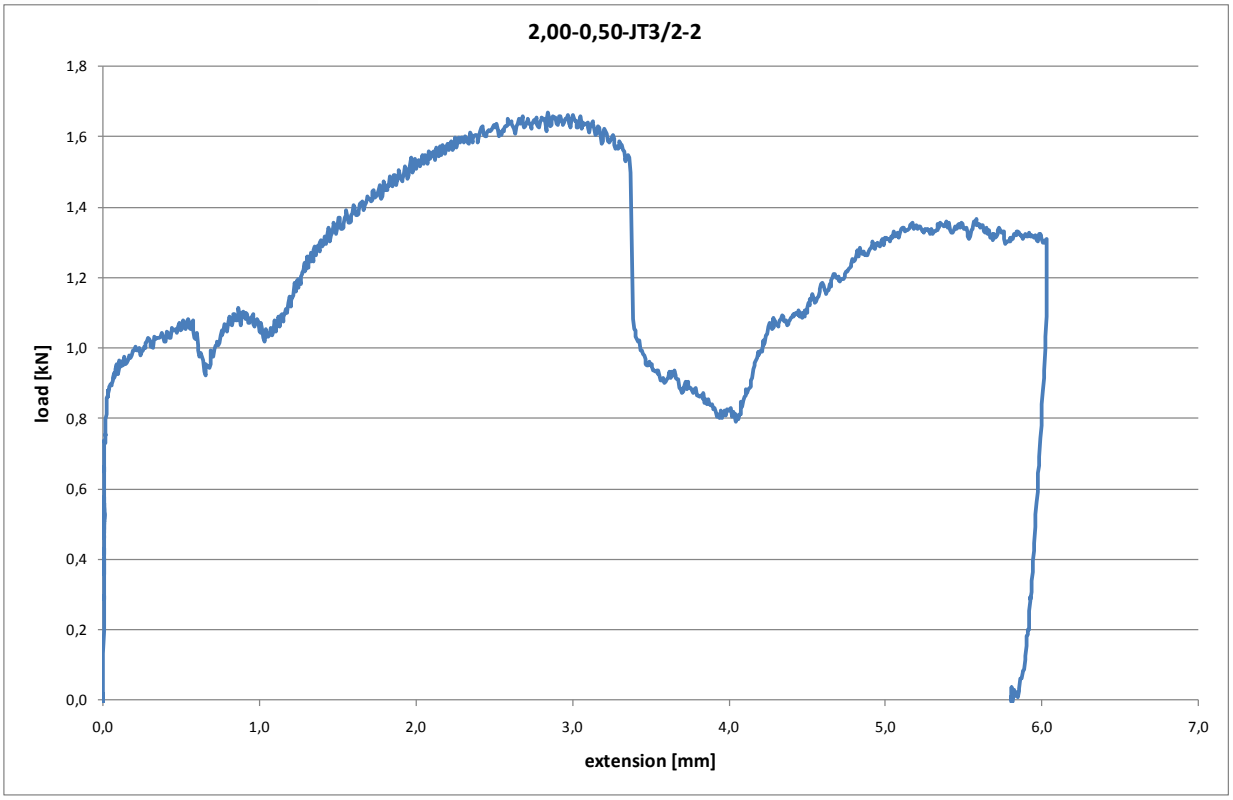
Tests on “thick to thin connections”

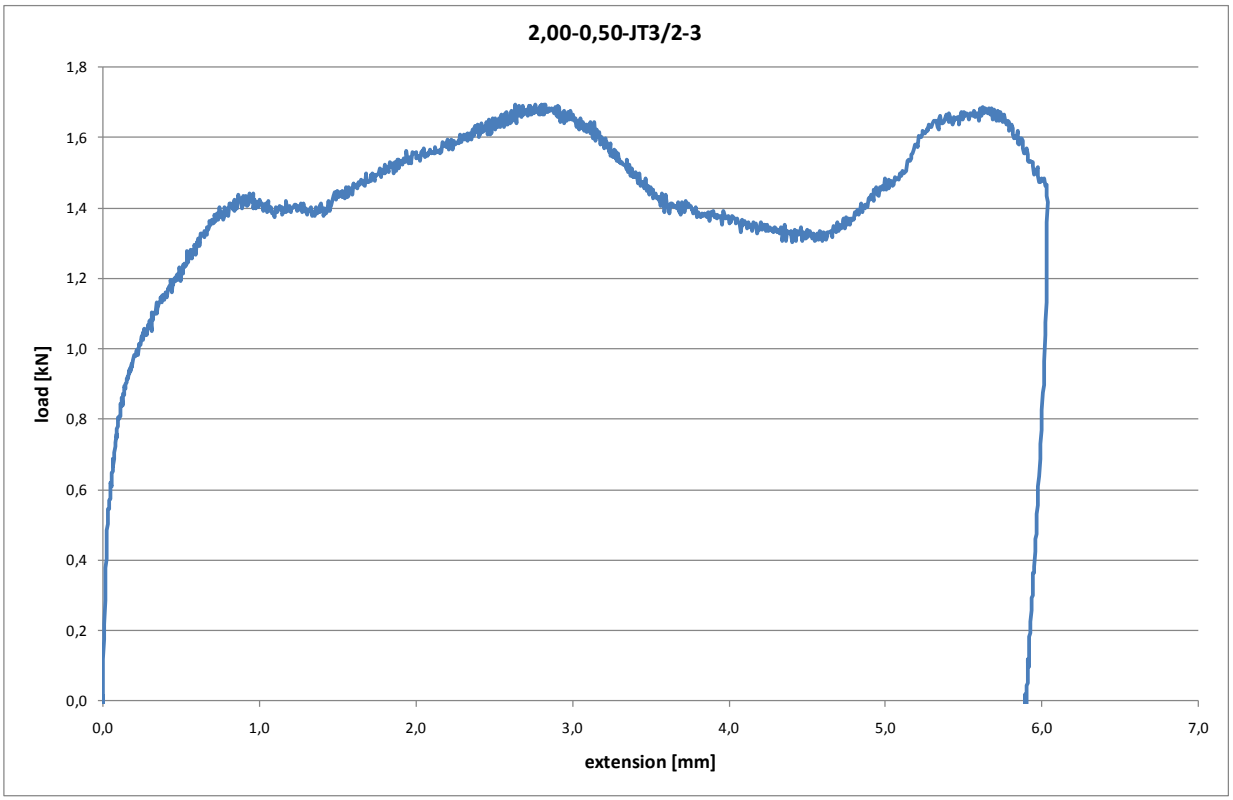
Thickness of steel section: 2,0 mm

Thickness of face sheet: 0,50 mm

Fastener: JT3-2-6,0xL




2,00-0,50-JT3/2-2
load [kN]
1,8
1,6
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0
extension [mm]

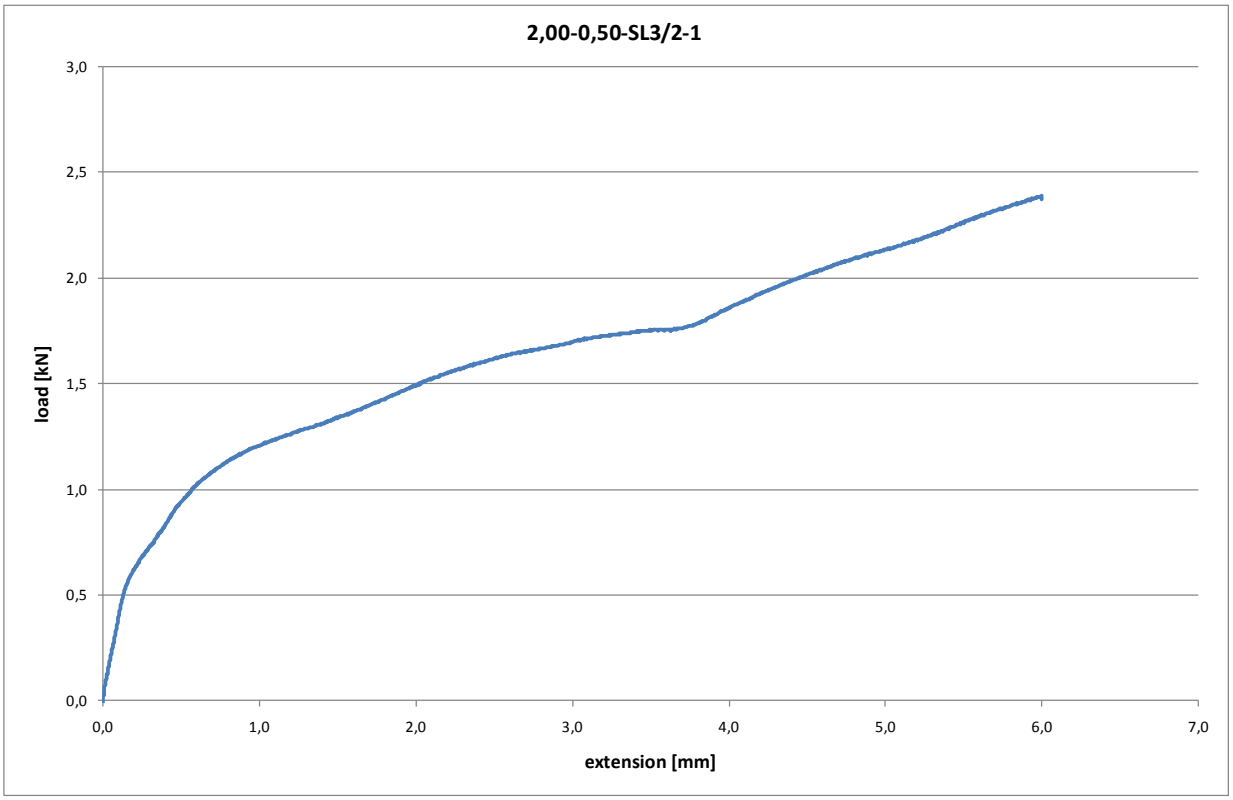

2,00-0,50-JT3/2-3
load [kN]
1,8
1,6
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0
extension [mm]

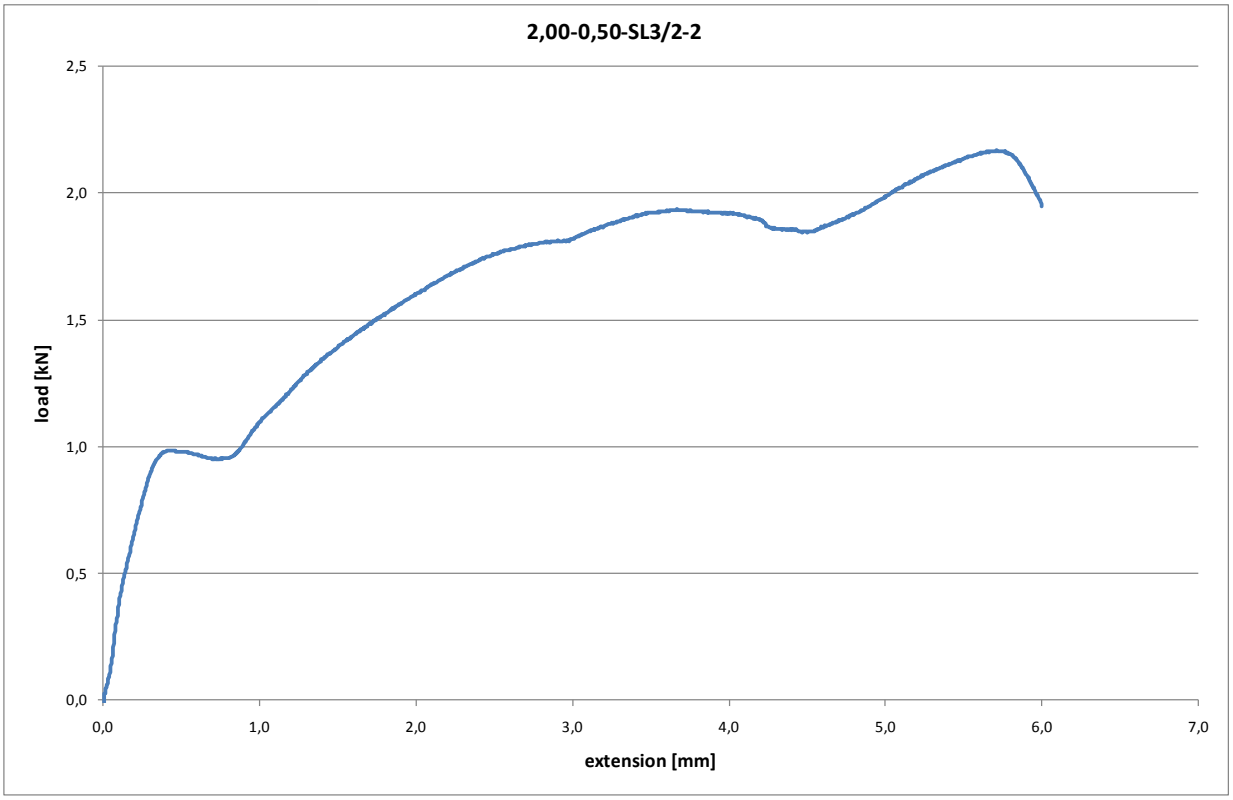
Tests on “thick to thin connections”

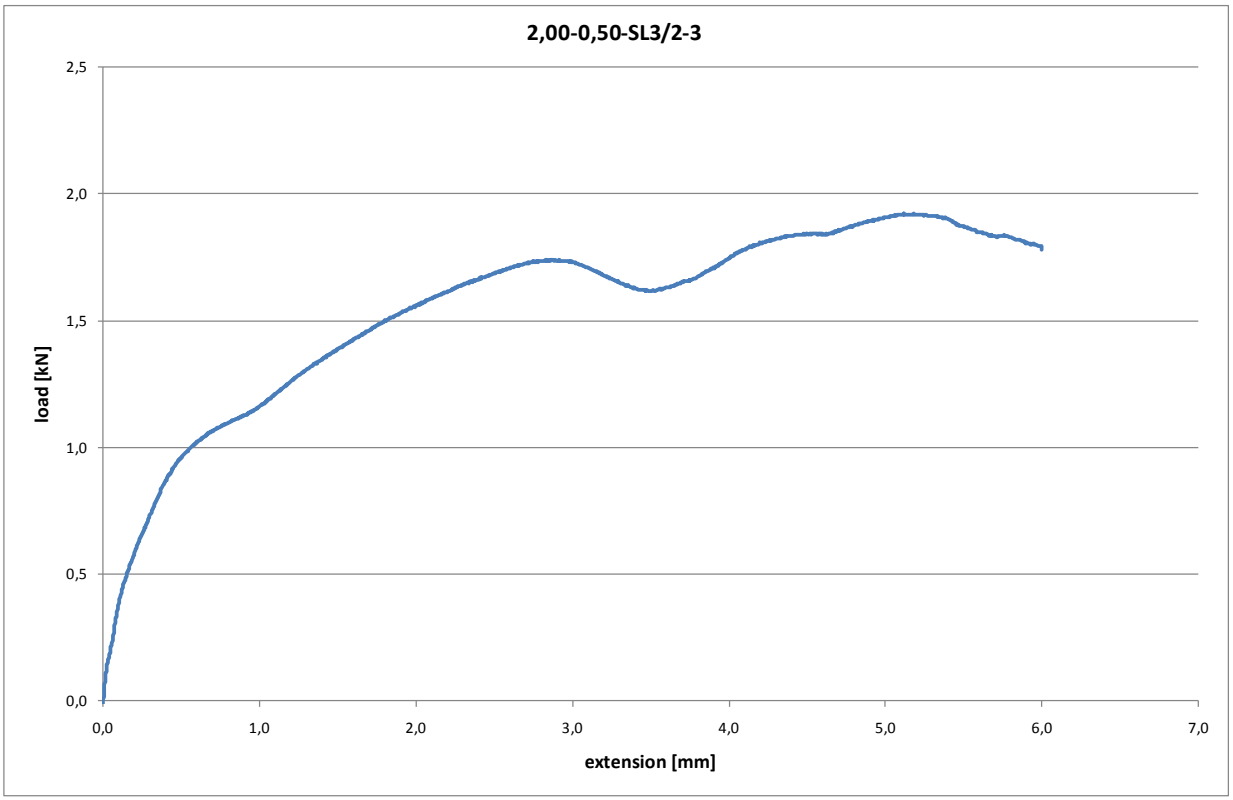
Thickness of steel section: 2,0 mm

Thickness of face sheet: 0,50 mm

Fastener: SL3/2-5-S-SV16-6,0xL




2,00-0,50-SL3/2-2
load [kN]
2,5
2,0
1,5
1,0
0,5
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0
extension [mm]

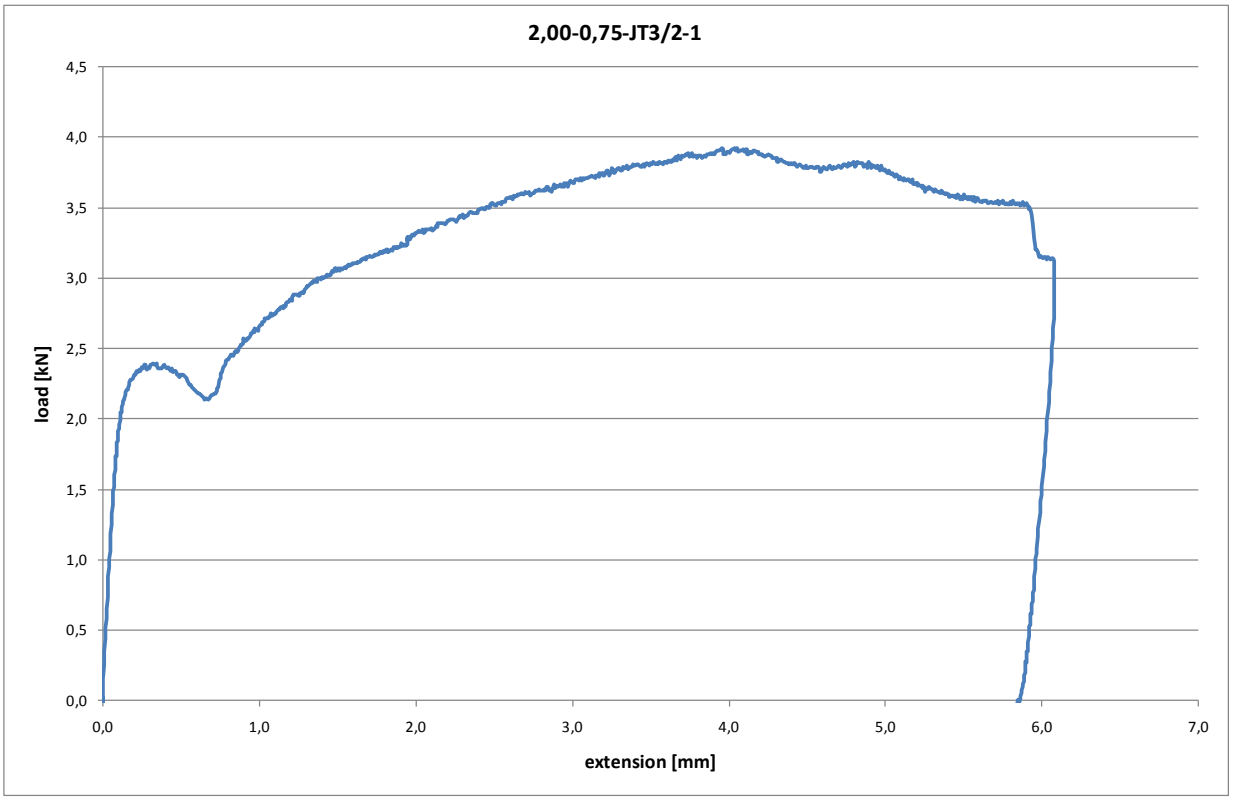

2,00-0,50-SL3/2-3
load [kN]
2,5
2,0
1,5
1,0
0,5
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0
extension [mm]

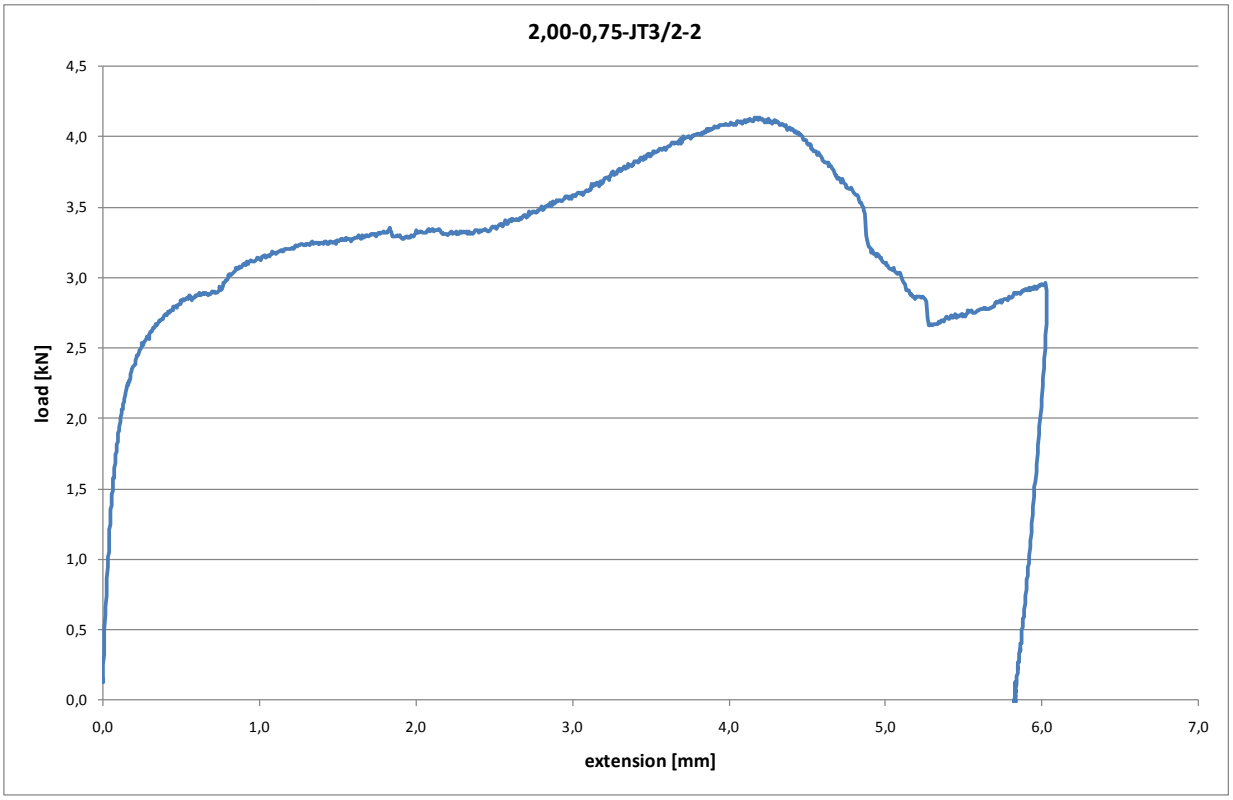
Tests on “thick to thin connections”

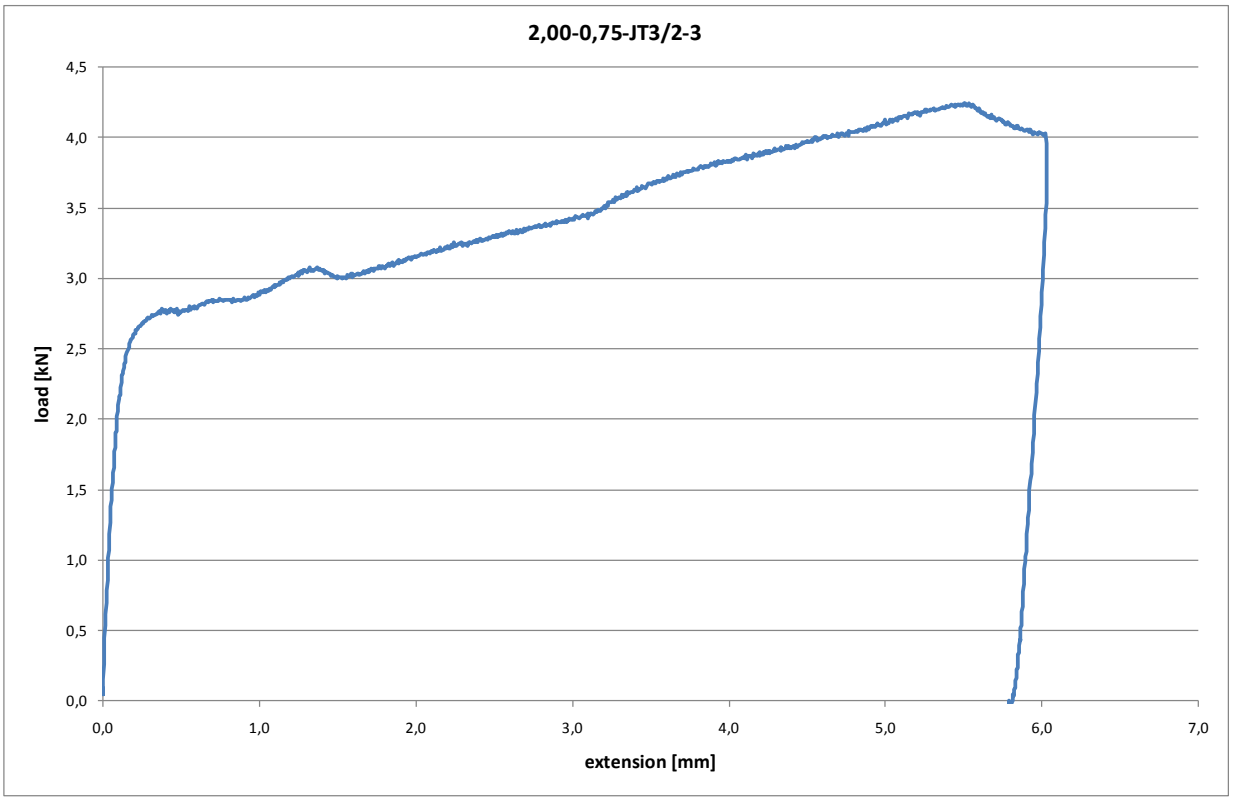
Thickness of steel section: 2,0 mm

Thickness of face sheet: 0,75 mm

Fastener: JT3-2-6,0xL




2,00-0,75-JT3/2-2
load [kN]
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0
extension [mm]

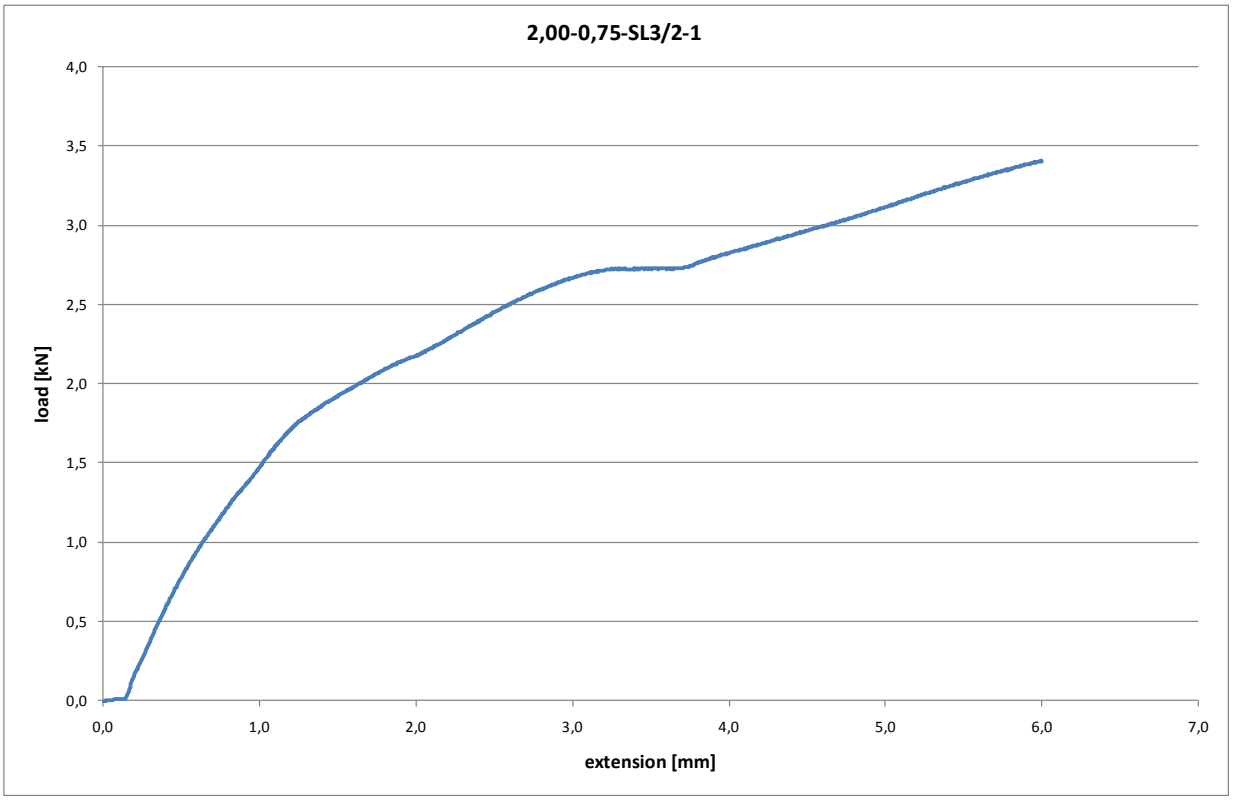

2,00-0,75-JT3/2-3
load [kN]
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0
extension [mm]

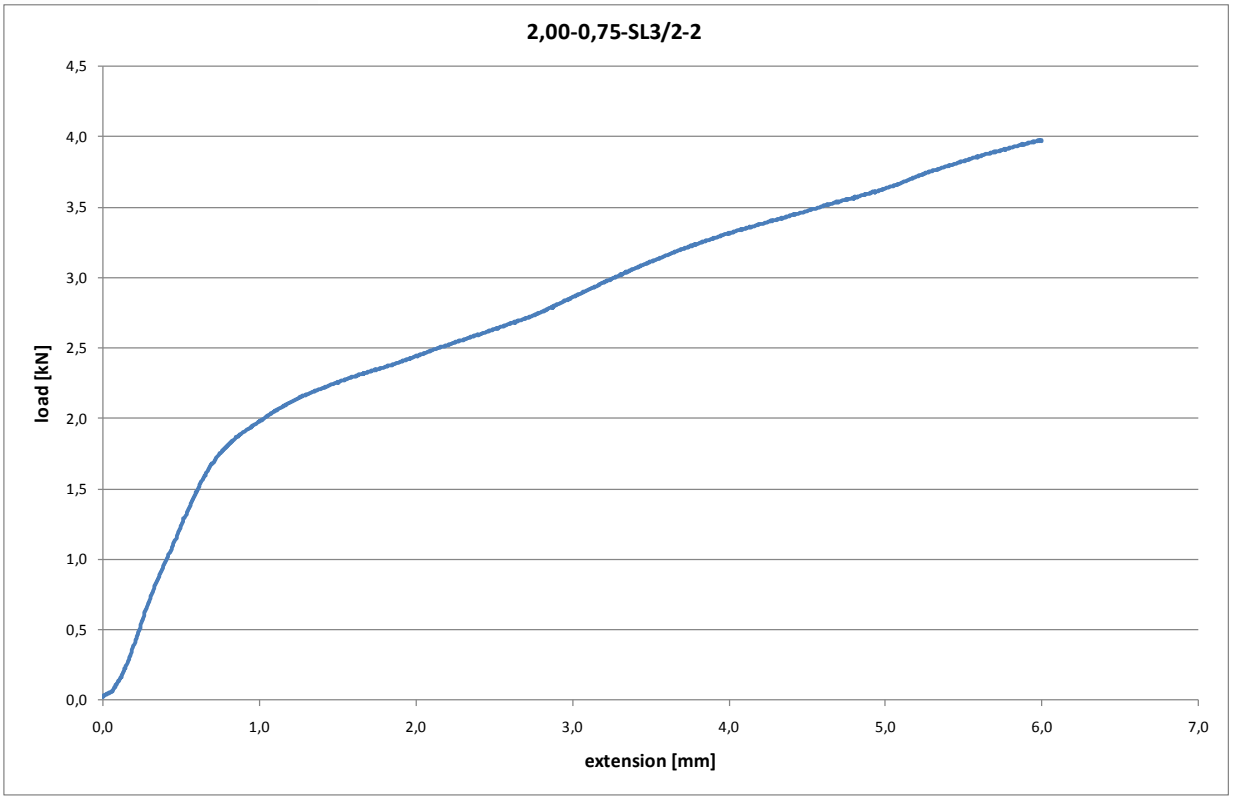
Tests on “thick to thin connections”

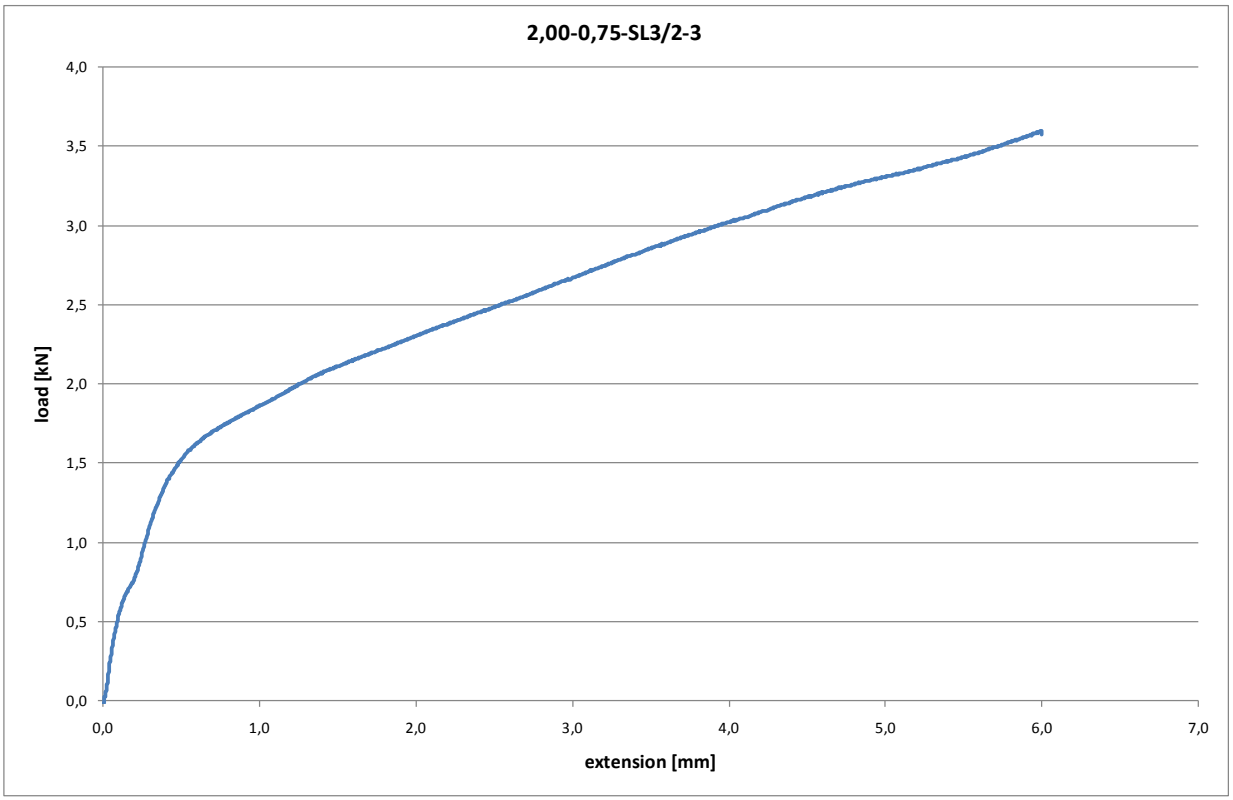
Thickness of steel section: 2,0 mm

Thickness of face sheet: 0,75 mm

Fastener: SL3/2-5-S-SV16-6,0xL




2,00-0,75-SL3/2-2
load [kN]
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0
extension [mm]


2,00-0,75-SL3/2-3
load [kN]
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0
extension [mm]