Nail and Nail Wire Bending Tests

Report prepared by

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Introduction

Stimulated by discussions in Working Group 1 (WG1) 'Test Methods' of CEN/TC 124 'Timber Structures' for drafting a CEN-Standard on the determination of the yield moment (bending resistance) of dowel-type fasteners by testing it was decided to carry out comparative tests with nails and nail wires of different types and material specifications.

It was of special interest to check the so-called revised NORDTEST Method using a special test device as well as the simple bending test method as described in the RILEM-Recommendation TT-1B, Annex B, which is identical with the former NORDTEST Method (1981). At the Danish Building Research Institute in Hørsholm, Marius Johansen developed in 1988 a test apparatus described in a document for the SBI-project R 13-78 (Nordtest project 710-87) titled 'Bending Strength of Nails - Testing of proposal for Nordtest-method'. In WG 1 of CEN/TC 124 this test method had been brought in as a basic paper for drafting a CEN-Standard. One of the main objectives was the principle, that the nail to be tested should be loaded in a manner that the loading points do not change their positions along the length of the nail. This can be verified by using a procedure shown in Fig. 1.

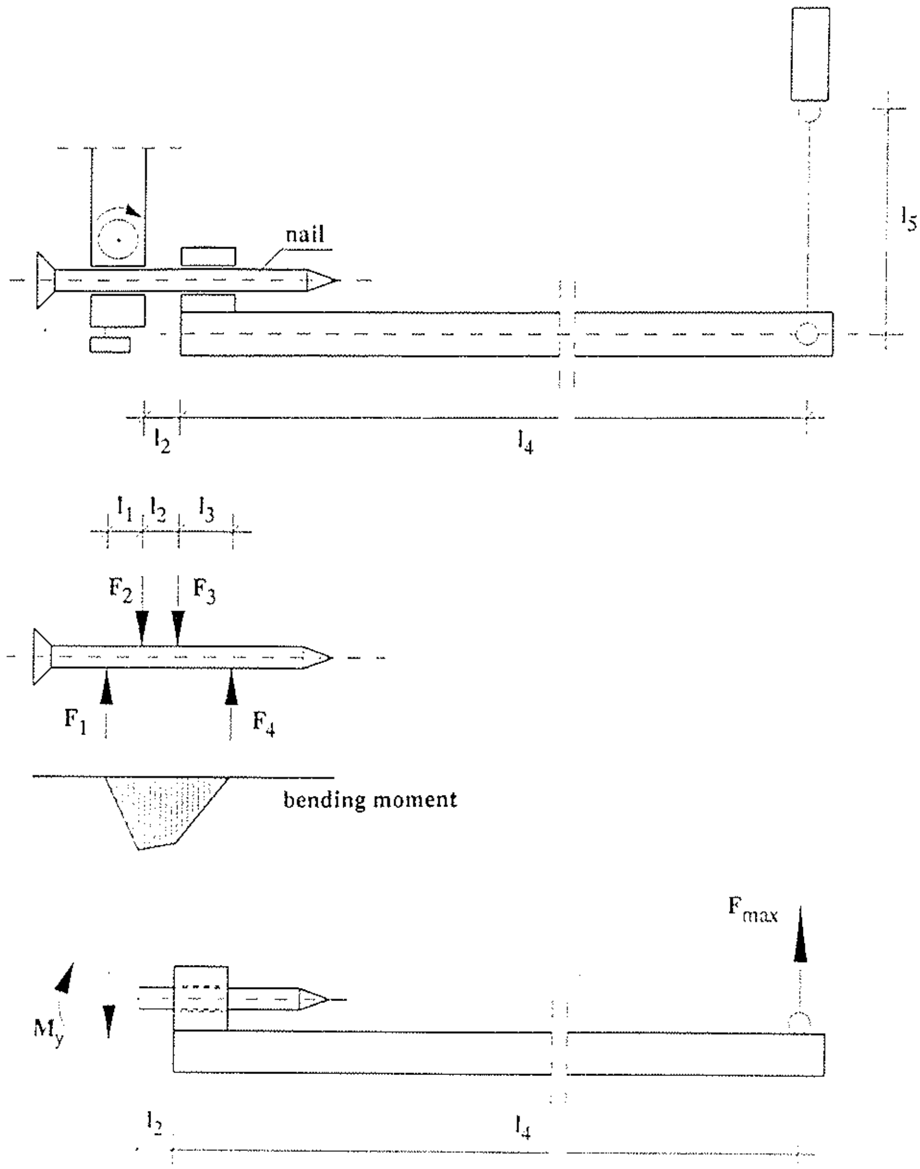

Fig. 1: Test set up and nail loading

A prototype test apparatus was built in the Timber Engineering Laboratory of the University of Karlsruhe using Johansen's idea. This apparatus and the test set-up are shown in Figs. 2 and 3. The nail or piece of wire is placed into a fixing device and bent directly by hand, see Fig. 4, or with a lever (for big nail diameters). The laod is measured with a calibrated load-cell and the bending angle of the nail is recorded by means of a potentiometer. Load-angle-diagrams are plotted.

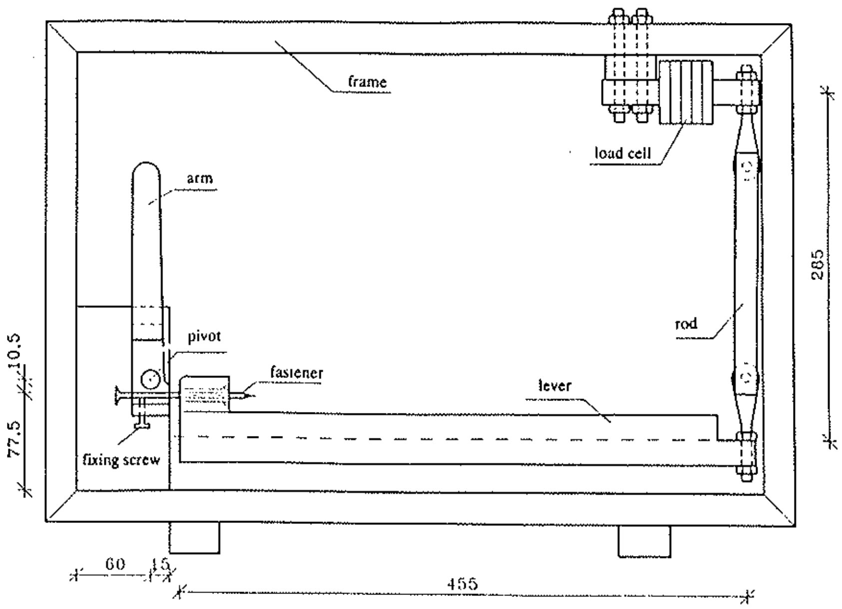

Fig. 2: Nail bending apparatus

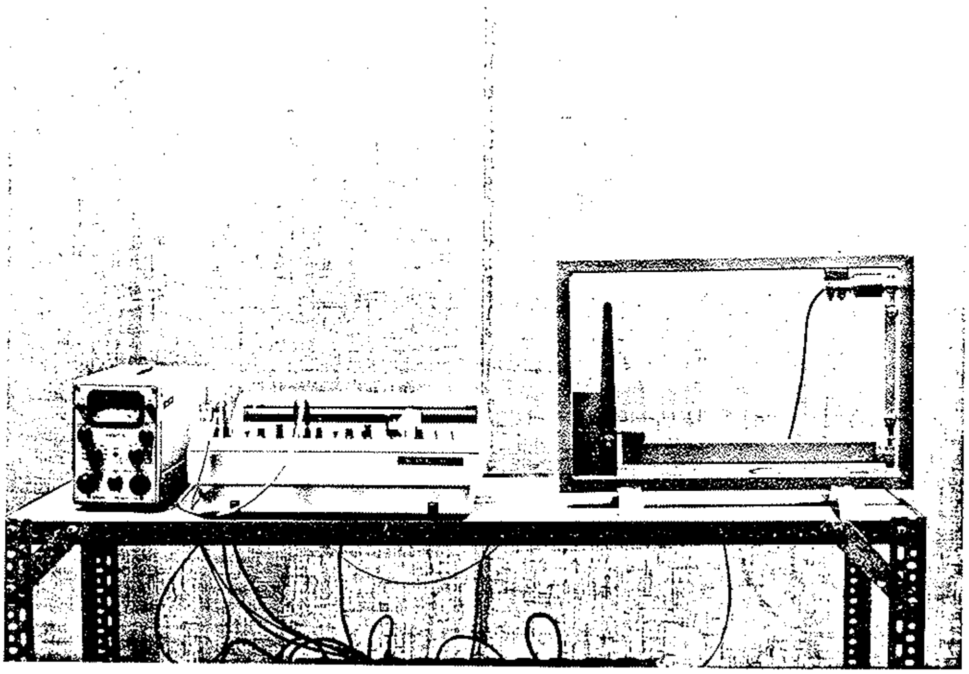

Fig. 3: Test set-up

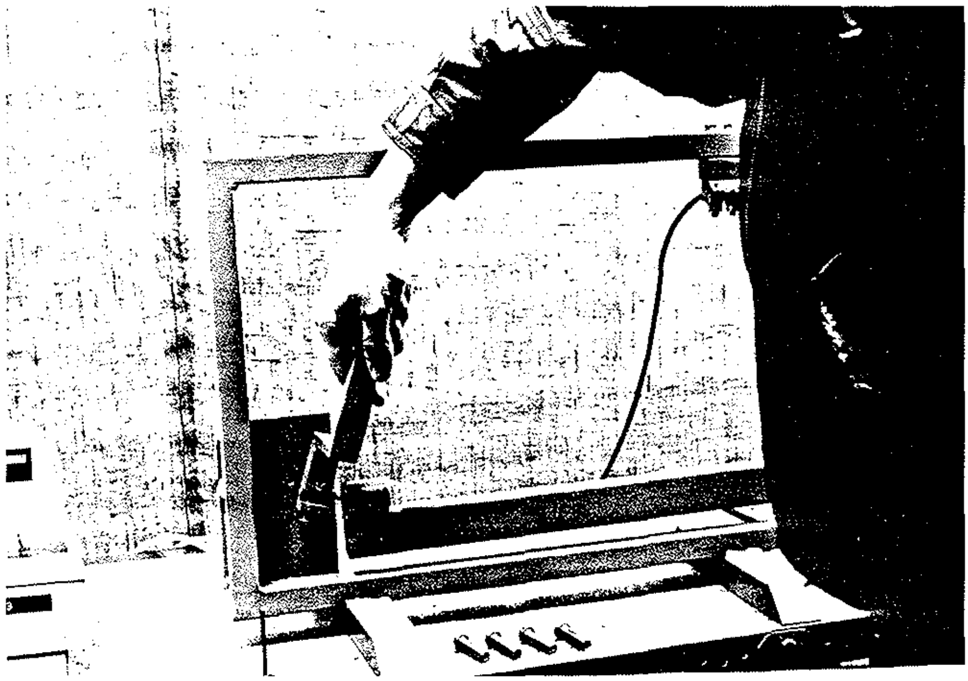

Fig. 4: Manual bending of nail

With this test apparatus nails or wires with a diameter up to 8 mm can be tested. The test speed is of no relevant influence on the test results. Thus, the tests are not very time-consuming. A bent nail in the test equipment is shown in Fig. 5.

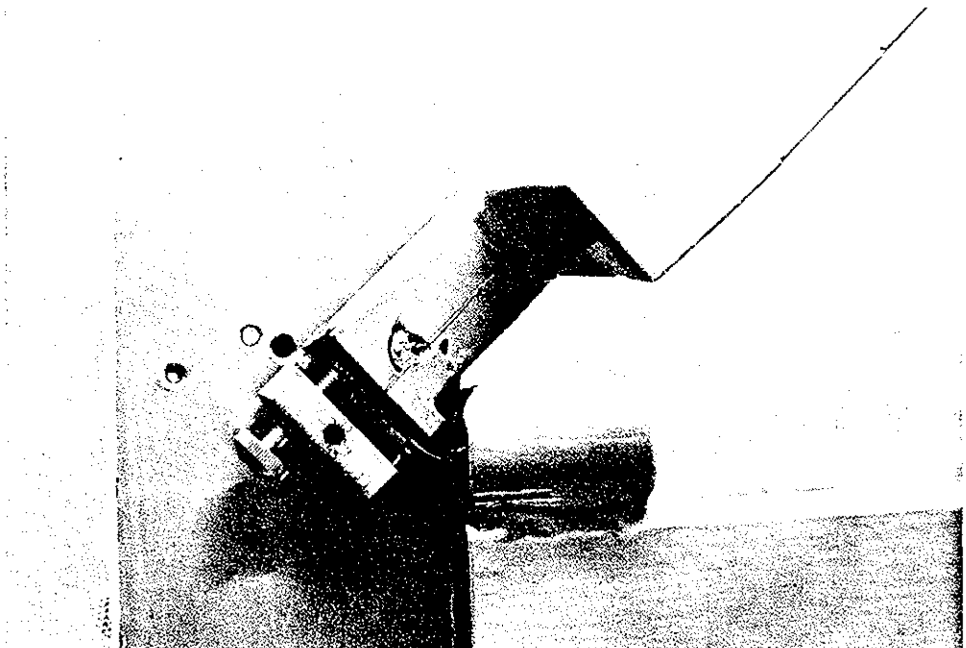

Fig. 5: Bent nail in test equipment

Tests and Test Results

The test programme comprised 38 different nails or wires with five tests, or ten tests each, respectively. The diameters ranged from 2.5 mm to 7.0 mm. The nail shanks were smooth, or helically threaded, or annularly threaded, respectively. The nail or wire material was different (common wire, hardened steel, stainless steel), and the surfaces of the nail shanks were blank, galvanized or hot-dipped, respectively. All nails or wires tested are listed in Table 1. In Fig. 6 some typical load-bending angle-diagrams of annularly threaded nails are shown (Fig. 6a: galvanized nails 6.0 x 100; Fig. 6b: stainless steel nails). Different types of nails yield different load-bending angle-diagrams. For common wire galvanized threaded nails an elastic-plastic behaviour can be assumed (see Fig. 6a), whereas for stainless steel threaded nails a kind of elastic limit can be noted with a continuous increasing of the load above this limit. Up to a bending angle of 50° to 60° unequivocal failures do normally not occur.

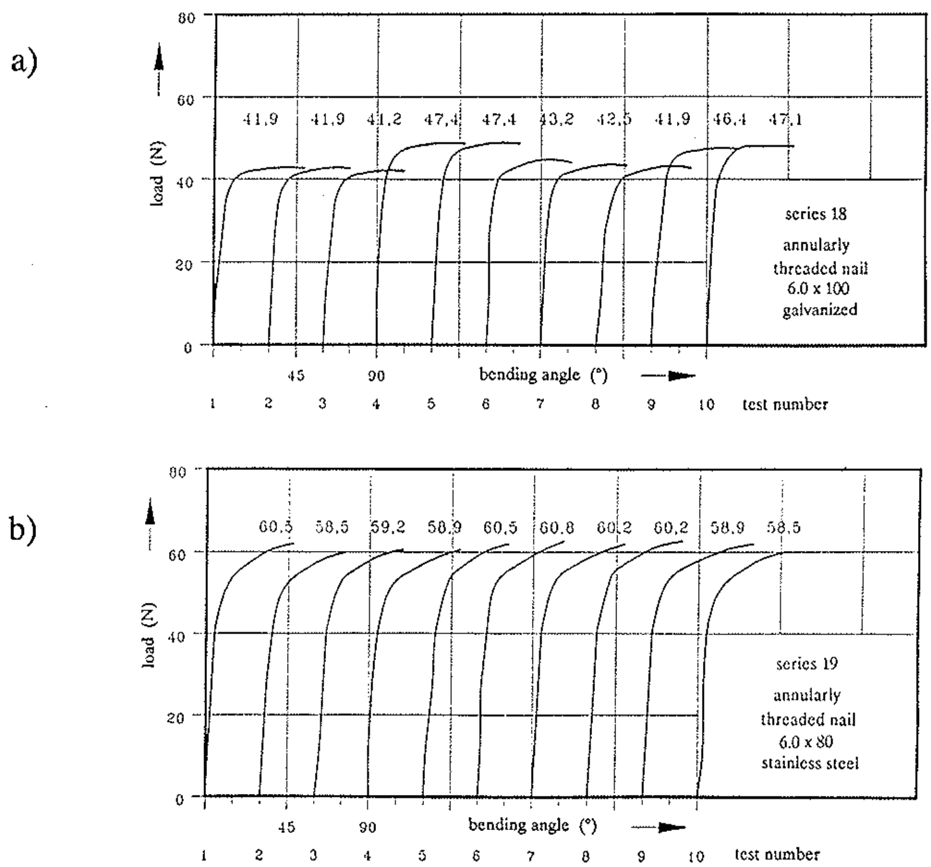

Fig. 6: Load-bending angle diagrams for galvanized and stainless annularly threaded nails

Table 1: Tested nails and wires

Series	Nail/ Manufacturer	Size $d_n \times l$*)	Profile	Surface/ Material	Diameter [mm] d_n	d_1	d_k
1a	A	3.8 x 105	smooth	hardened	3.80	3.80	3.80
1b	A	3.8 x 105	smooth	hardened	3.80	3.80	3.80
2	A	3.8 x 120	smooth	hardened	3.80	3.80	3.80
3	B	2.8 x 65	helically threaded	stainless	2.80	3.20	2.50
4	B	3.1 x 80	helically threaded	stainless	3.10	3.60	2.80
5	DIN 1151	2.5 x 55	smooth	blank	2.50	2.50	2.50
6	DIN 1151	3.4 x 80	smooth	blank	3.40	3.40	3.40
7	DIN 1151	4.2 x 110	smooth	blank	4.20	4.20	4.20
8	DIN 1151	6.0 x 180	smooth	blank	6.00	6.00	6.00
9	DIN 1151	7.0 x 210	smooth	blank	7.00	7.00	7.00
10	C	wire	smooth	untreated	6.00	6.00	6.00
10a	C	wire	smooth	untreated	3.96	3.96	3.96
11	C	4.0 x 75	annularly threaded	galvanized	4.02	4.38	3.62
12	C	6.0 x 100	annularly threaded	galvanized	6.07	6.47	5.70
13	D	wire	smooth	untreated	3.09	3.09	3.09
13a	D	wire	smooth	stainless	3.08	3.08	3.08
14	D	wire	smooth	untreated	3.98	3.98	3.98
14a	D	wire	smooth	stainless	3.97	3.97	3.97
15	D	wire	smooth	untreated	5.98	5.98	5.98
15a	D	wire	smooth	stainless	5.98	5.98	5.98
16	D	4.0 x 75	annularly threaded	galvanized	4.02	4.32	3.75
17	D	4.0 x 50	annularly threaded	stainless	4.07	4.34	3.53
18	D	6.0 x 100	annularly threaded	galvanized	6.04	6.34	5.62
19	D	6.0 x 80	annularly threaded	stainless	5.98	6.38	5.52
20	E	4.0 x 60	annularly threaded	galvanized	3.99	4.36	3.70
21	E	wire	smooth	untreated	3.99	3.99	3.99
22	DIN 1151	3.1 x 65	smooth	blank	3.10	3.10	3.10
23	B	2.8 x 65	helically threaded	stainless	2.80	3.20	2.50
24	F	2.9 x 63	annularly threaded	sherardized	2.90	3.20	2.50
25	F	2.9 x 63	annularly threaded	stainless	2.90	3.20	2.50
26	D	3.1 x 65	helically threaded	hot-dipped	3.01	3.07	2.05
27	G	3.1 x 80	helically threaded	stainless	3.10	3.50	2.80
28	DIN 1151	2.5 x 60	smooth	blank	2.50	2.50	2.50
29	DIN 1151	4.2 x 110	smooth	blank	4.20	4.20	4.20
30	H	3.1 x 60	annularly threaded	galvanized	3.10	3.30	2.75
31	H	4.0 x 75	annularly threaded	galvanized	4.00	4.40	3.75
32	H	6.0 x 100	annularly threaded	galvanized	6.00	6.40	5.65
33	DIN 1151	3.1 x 80	smooth	blank	3.10	3.10	3.10

*) l = nail length [mm]

The test results are listed in Table 2, containing among others the mean values of the yield moments of the nails and its coefficient of variation. From the tested nail wires the tensile strength was determined in separate tests.

For all smooth round-wire nails the yield stress was calculated from the tested yield moment using the formula

$$f_y = M_y/W_y$$

with $W_y = d_n^3/6$.

It can be seen that these yield stress values are not identical with the yield stress of the wire found in regular wire tension tests. The yield stress values derived this way may even be higher than the regular tensile strength of the wire due to the different definition of these material properties.

The calculated yield stress of round wire nails according to the German nail standard DIN 1151 depends significantly on the nominal nail diameter. The single test values and the respective regression lines for the mean values and the 5-percentiles are shown in Fig. 7.

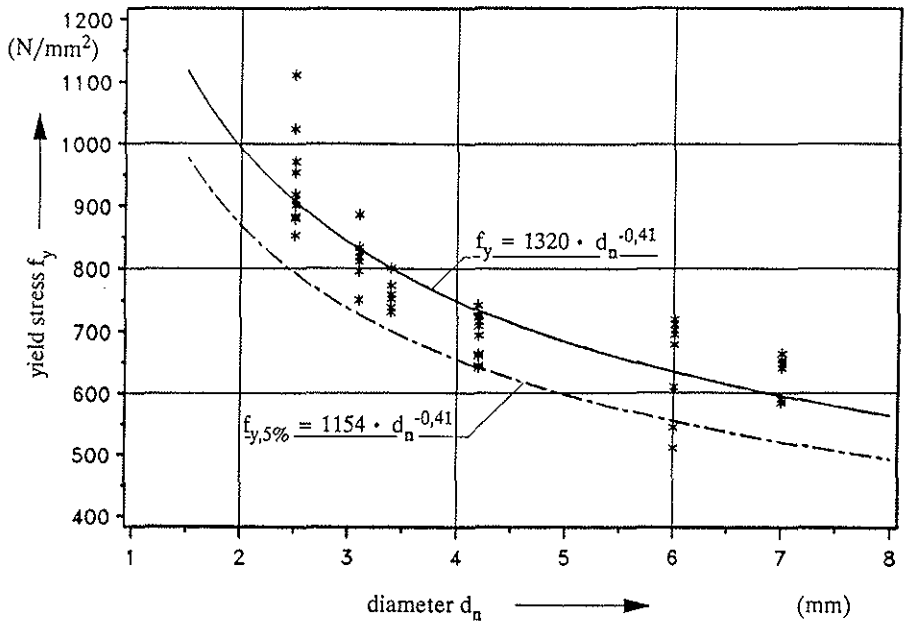

Fig. 7: Calculated yield stress f_y of nails according to DIN 1151 depending on diameter d_n

Table 2: Test results

Series	Nail/ Manu-facturer	Size d_n x l*)	Nominal diameter d_n [mm]	Number of tests	Tensile strength of nail wire f_t [N/mm²]	Yield moment of nail M_y [Nm]	Coefficient of variation V [%]	Calculated yield stress f_y [N/mm²]
1a	A	3.8 x 105	3.8	5	-	20.10	3.5	2198
1b	A	3.8 x 105	3.8	5	-	19.84	2.1	2170
2	A	3.8 x 120	3.8	10	-	18.92	5.1	2069
3	B	2.8 x 65	2.8	10	-	3.70	1.6	1420
4	B	3.1 x 80	3.1	10	-	5.17	2.3	1413
5	DIN 1151	2.5 x 55	2.5	10	-	2.35	3.5	902
6	DIN 1151	3.4 x 80	3.4	10	-	5.02	3.0	767
7	DIN 1151	4.2 x 110	4.2	10	-	8.83	2.1	715
8	DIN 1151	6.0 x 180	6.0	10	-	23.28	11.7	647
9	DIN 1151	7.0 x 210	7.0	10	-	36.20	5.3	633
10	C	wire	6.0	5	705	27.51	0.9	777
10a	C	wire	3.96	5	723	8.05	1.4	775
11	C	4.0 x 75	4.02	10	-	7.24	2.2	916
12	C	6.0 x 100	6.07	10	-	26.46	4.1	857
13	D	wire	3.09	5	792	4.24	1.6	863
13a	D	wire	3.08	3	752	3.12	-	641
14	D	wire	3.98	5	636	7.53	4.4	716
14a	D	wire	3.97	3	759	7.21	1.6	691
15	D	wire	5.98	5	722	28.15	0.8	790
15a	D	wire	5.98	3	614	18.55	3.7	521
16	D	4.0 x 75	4.02	10	-	6.65	1.6	756
17	D	4.0 x 50	4.07	10	-	9.09	0.8	1240
18	D	6.0 x 100	6.04	10	-	20.28	6.0	686
19	D	6.0 x 80	5.98	10	-	27.43	1.5	978
20	E	4.0 x 60	3.99	10	-	7.50	1.0	889
21	E	wire	3.99	5	714	7.93	4.8	749
22	DIN 1151	3.1 x 65	3.10	5	-	4.08	6.0	821
23	B	2.8 x 65	2.8	5	-	3.86	3.0	1482
24	F	2.9 x 63	2.90	5	-	2.45	8.5	941
25	F	2.9 x 63	2.90	5	-	3.40	3.3	1306
26	D	3.1 x 65	3.1	5	-	3.47	1.2	1334
27	G	3.1 x 80	3.1	5	-	5.76	3.0	1574
28	DIN 1151	2.5 x 60	2.50	5	-	2.64	6.4	1014
29	DIN 1151	4.2 x 110	4.20	5	-	8.02	1.7	650
30	H	3.1 x 60	3.10	5	-	2.94	5.7	848
31	H	4.0 x 75	4.00	5	-	8.11	0.8	923
32	H	6.0 x 100	6.00	5	-	20.37	5.7	678
33	DIN 1151	3.1 x 80	3.10	5	-	4.07	1.8	819

*) l = nail length [mm]

As a substantial result of these tests it can be stated that from the yield moment or the yield stress of the nail wire the effective yield moment of the nail made of this wire can not be derived. Thus, for round wire nails as well as for all types of nails with a profile shank the yield moment should be assessed by the nail bending test. The test procedure described turned out to be a good method and can be supported to become an international test standard. It is desirable to develop a test apparatus suitable to test the yield moment of dowel-type fasteners with diameters up to 30 mm. This task has been started. A report will be submitted at a given time.