Dr. Zapfe GmbH
Ingenieurbüro

Dr. Zapfe GmbH
Engineering office for structural engineering and solar technology
Alustr.1
D- 83527 Kirchdorf/Haag i.OB

Phone: +49 8072 9191 280
Fax: +49 8072 9191 9280
Mobile: +49 176 19191280

E-Mail: cedrik.zapfe@ing-zapfe.de
hhttp://www.ing-zapfe.de

Test documentation 2011-112

Screw pull-out tests on wooden rafters with a rafter width of 35 mm

Client:

Schletter Solar GmbH
Alustrasse 1

D- 83527 Kirchdorf/Haag i.OBB

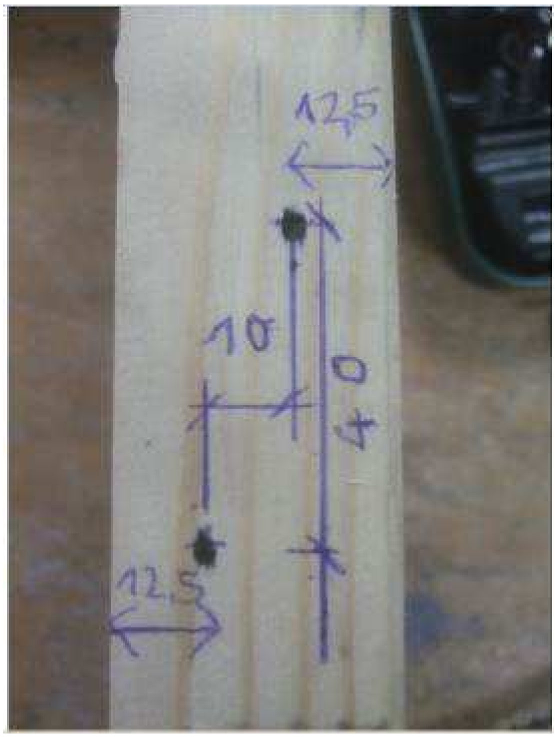
August 2011

Screw pull-out tests on wooden rafters with a rafter width of 35 mm

1. General

The subject of the load-bearing tests documented below is the experimental determination of the pull-out resistance of different screw types in spruce wood rafter with a thickness of 35 mm. Alternatively, identical constellations with and without pre-drilling were tested. According to DIN EN 1995 (Eurocode 5) respectively DIN 1052, for a screw with a diameter of d = 6 mm, that has been pre-drilled with a diameter 0.7·d, there should be a wood width of 3·d+10+3·d = 46 mm for the specific hole pattern. As the normative regulations cannot be maintained with rafters with a thickness of 35 mm, several test series were carried out. The spruce wood that was used had the quality classification C10.

Picture 1 35mm wide spruce wood rafter



Picture 2 Screw picture of both screws into the spruce wood rafter that has a width of 35 mm

2. Test procedure

The purpose of the tests was the experimental determination of the pull-out resistance of different screw types and screwing situations in wooden rafter with a width of 35 mm.

2.1 High-grade steel 6.0x90mm according Din 571 without pre-drilling. Screwed into the spruce wood down to a depth of 60 mm.

Picture 3 6.0x90 Din 571 without pre-drilling

Picture 4 minor splitting effect

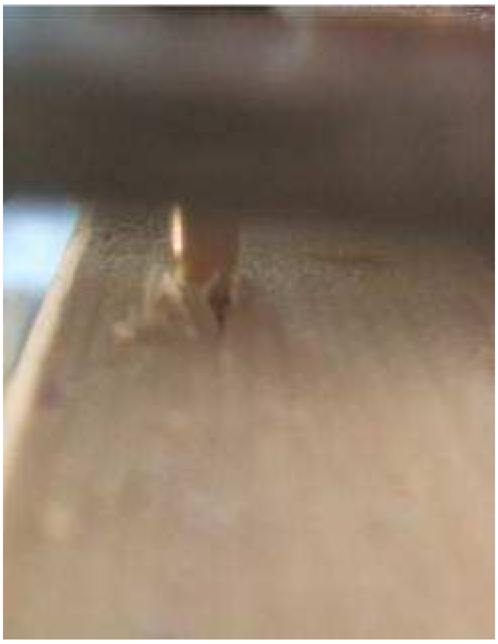
2.2 High-grade steel 6.0x90mm according to DIN 571 screwed down to a depth of 60 mm into the spruce wood in 4mm pre-drilled holes.

Picture 5 4mm pre-drilled holes

Picture 6 no visible splitting effect

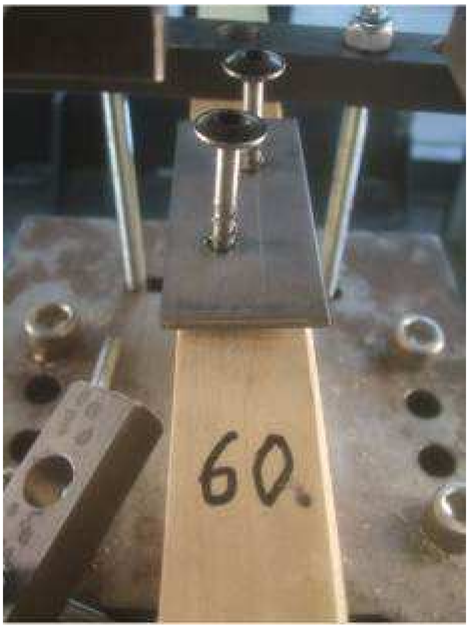
2.3 6.0x80mm spax screw screwed into the spruce wood without pre-drilling down to a depth of 60 mm using a Torx T30 drive;

Picture 7 6.0x90 Din 571 spax screw



Picture 8 minor splitting effect

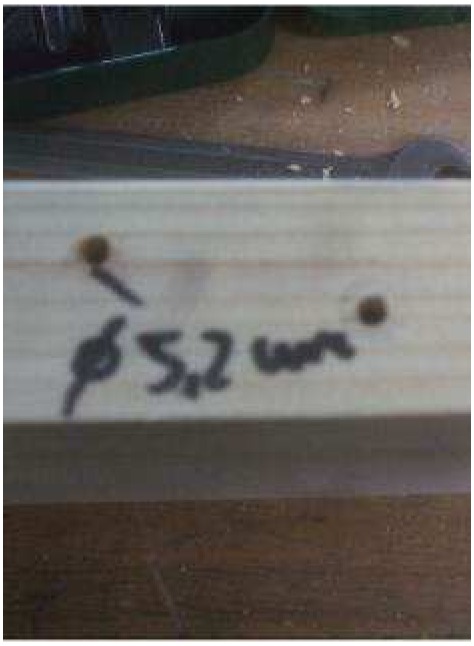
2.4 8.0x100mm wafer-head screw screwed into the spruce wood down to a depth of 60 mm with a Torx T30 drive without pre-drilling;



Picture 9 8.0 x 100 wafer-head screw
Screwed down to a depth of 60 mm

Picture 10 no visible splitting effect

2.5 8.0x100 mm with a waver-head screw high-grade steel 1.4567 screwed down to a depth of 60 mm with Torx T40 drive in 5.2 mm pre-drilled holes



Picture 11 5.2 mm pre-drilled holes

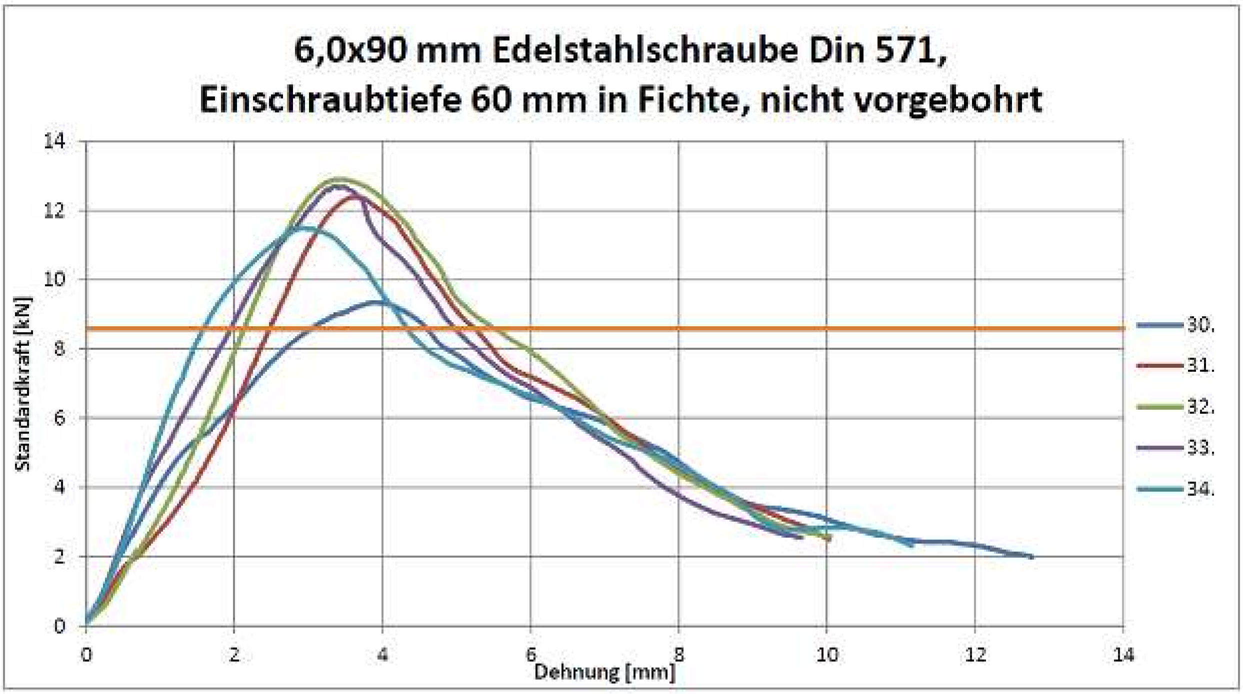
Picture 12 no visible splitting effect

The tests were carried out on a servo-hydraulic testing machine made by Zwick. Force and deformation were continuously digitally recorded. The test program included 5 uniform tests as a basis for the evaluation of dispersions and a statistical evaluation.

3. Test results

In the charts below, the test records of 5 uniform pull-out tests are shown. The failure criterion always was the breaking-out of the screws of the spruce wood. The screws did not show any remaining deformations or signs of imminent component failure.

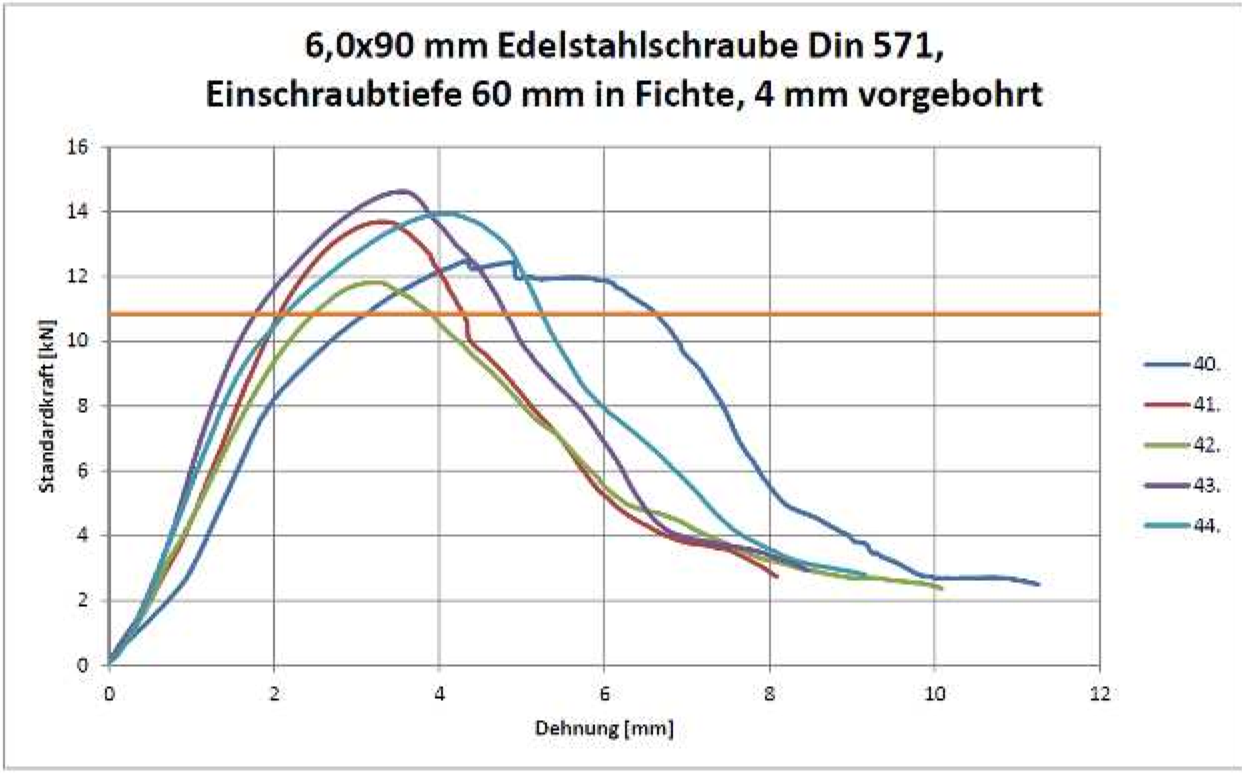
3.1 Test results of the pull-out tests with high-grade steel screws 6.0x90 without pre-drilling



Picture 13 Record of the pull-out tests 6.0x90mm; not pre-drilled

Picture 14 Failure picture of the pulled out screws

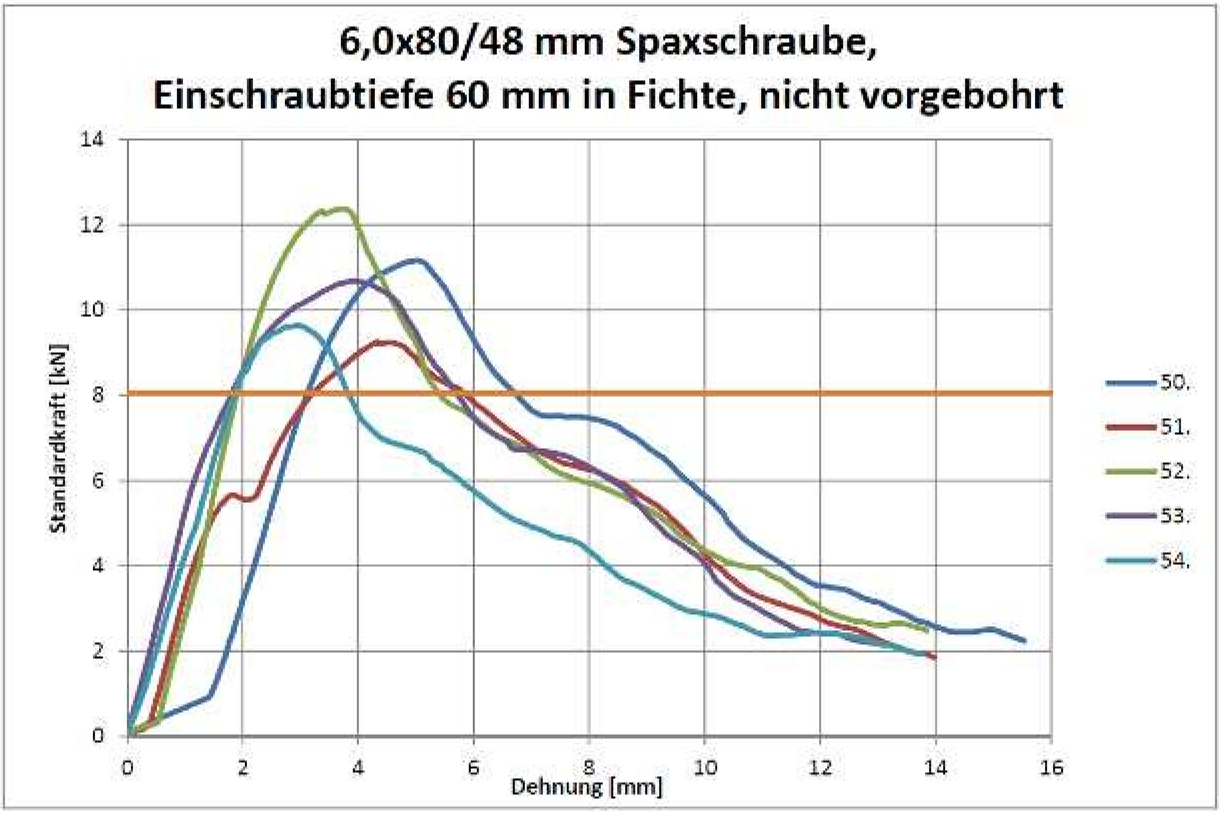
3.2 Test results of the pull-out tests with high-grade steel screws 6.0x90, 4 mm without pre-drilling



Picture 15 Test records of the pull-out tests 6.0x90mm; 4mm pre-drilled

Picture 16 Breakage picture of the pulled out screws

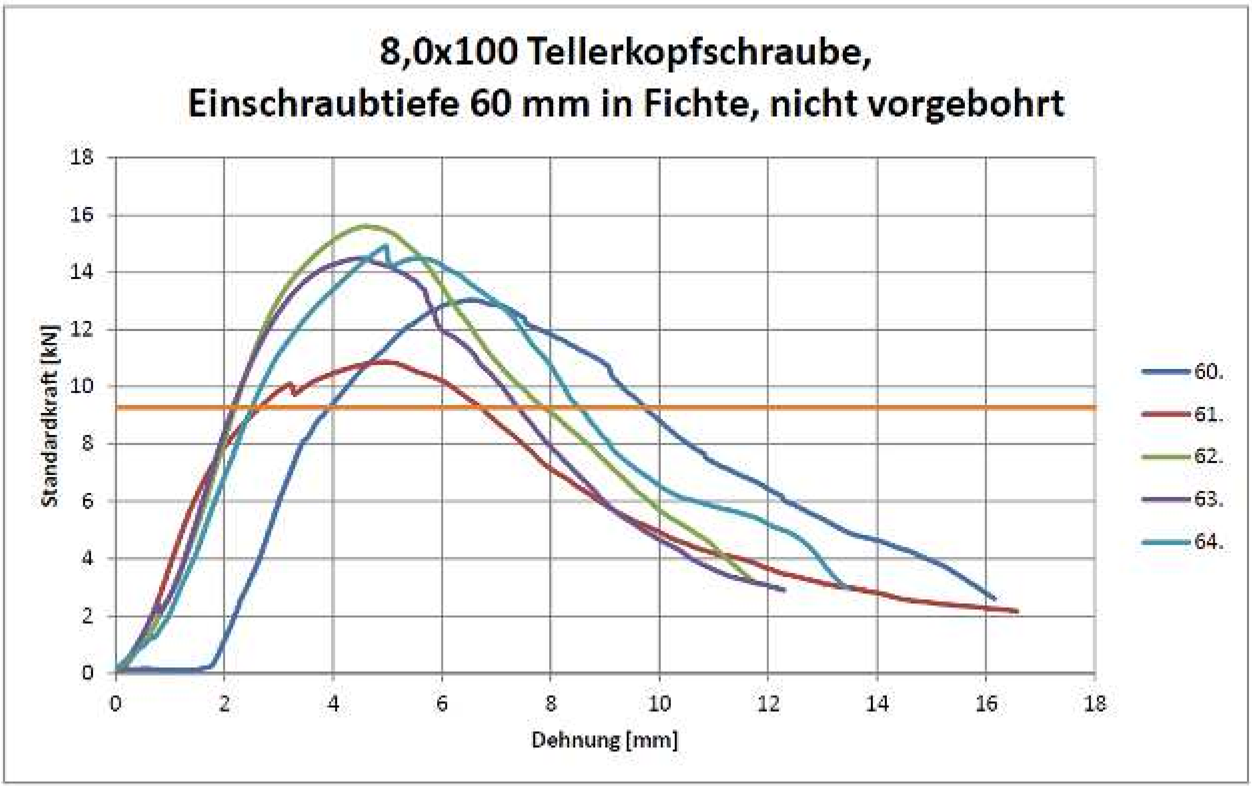
3.3 Test results of the pull-out tests with high-grade spax screws 6.0x80 without pre-drilling



Picture 17 Record of the pull-out tests 6.0x80mm; not pre-drilled

Picture 18 Breakage picture of the pulled out screws

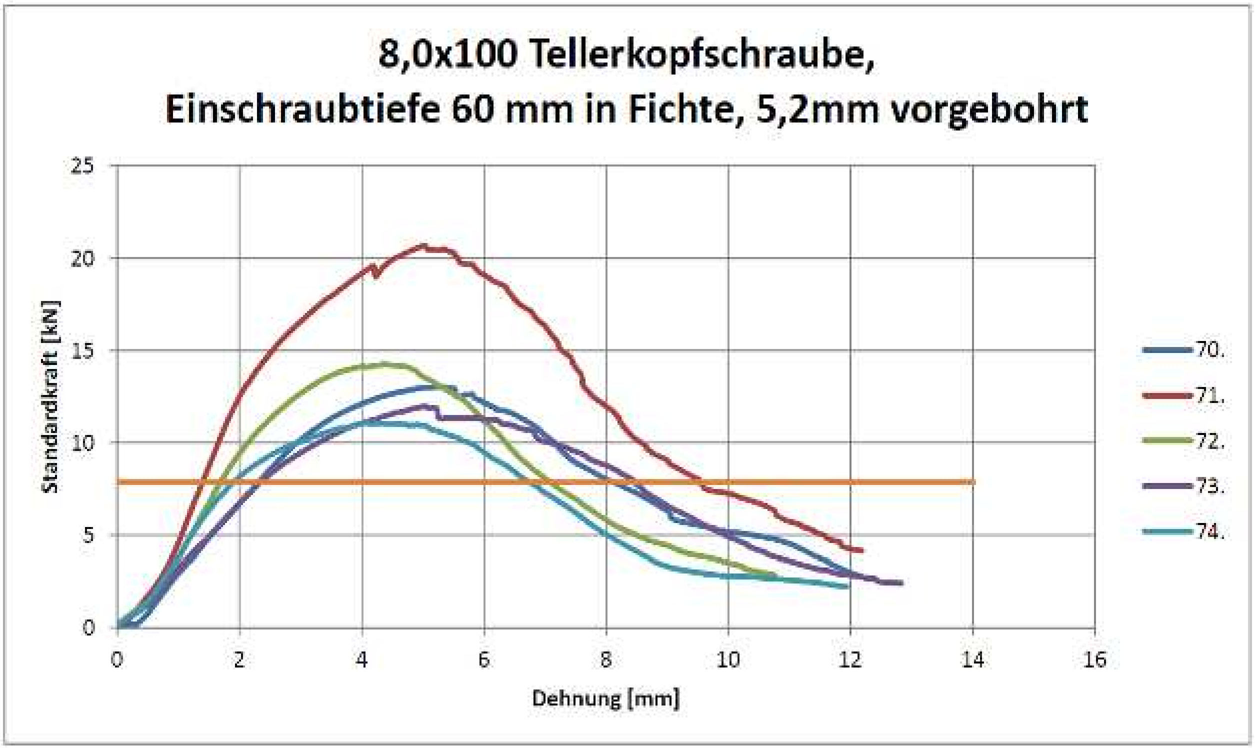
3.4 Test results of the pull-out tests with 8.0x100mm wafer-head screws without pre-drilling.



Picture 19 Record of the pull-out tests 8.0x100mm wafer-head screw; not pre-drilled

Picture 20 Breakage picture of the pulled out screws

3.5 Test results of the pull-out tests with 8.0x100mm wafer-head head screws, 5.2 mm pre-drilled.



Picture 21 Record of the pull-out test 8.0x100mm wafer-head screw; 5.2mm pre-drilled

Picture 22 Breakage picture of the pulled out screws

4. Statistical evaluation

Usually, there will be divergent test curves when several tests are carried out. Depending on the material, the type of test and the failure mechanisms, there will be dispersions of the test values. The aim of a statistical evaluation is the determination of verified values that will not be under-cut with a defined probability. In the sector of structural engineering, the 5%-fractile is the usual measure for the determination of the characteristic load-bearing capacity. The determination of the characteristic load-bearing capacity is carried out on the basis of the Eurocode 1 (DIN EN 1990), attachment D. Based on a log-normal distribution of the evaluation value, the characteristic load-bearing capacity can be determined using the following equation:

$P_{Rk} = \exp(m_y - k_n \cdot s_y)$

with:

m_y Average value of the logarithms of the test values

s_y Standard deviation

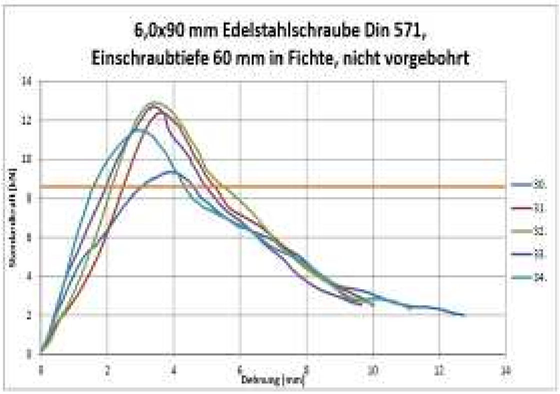
k_n Fractile factor for unknown variance according to EN 1990 chart D.1

The statistical evaluations of the test series is shown tabularly and graphically in picture 7.

Statistical evaluation according to EC1 attachment

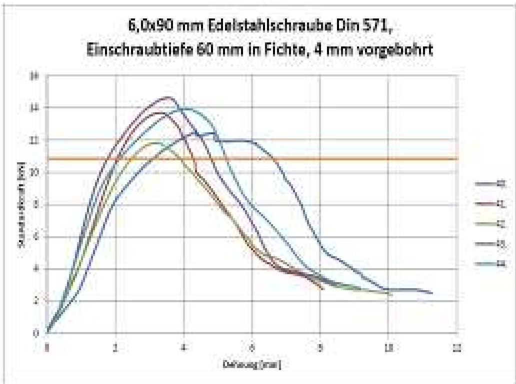
4.1 6.0x90 mm high-grade steel screw DIN 571; not pre-drilled

		x_i		$\ln x_i$	
S_1	=	9,35219043	kN	2,23561059	0,04989942
S_2	=	12,3889111	kN	2,51680181	0,00334193
S_3	=	12,8952699	kN	2,55686057	0,00957818
S_4	=	12,7154717	kN	2,54281949	0,00702699
S_5	=	11,5060088	kN	2,4428694	0,00025995
Mittelwert		**11,7715704**	**kN**	**Summe**	**0,07010647**
				2,45899237	
m_y	=	2,45899237			
s_y	=	0,13238814		Anzahl Versuche	
k_n	=	2,33		5	
P_{Rk}	=	8,59 kN			
P_{Rd}	=	6,87 kN			



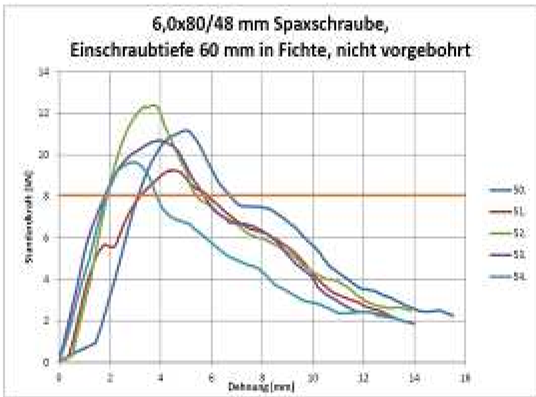
4.2 6.0x90 mm high-grade steel screw DIN 571; 4 mm pre-drilled

		x_i		$\ln x_i$	
S_1	=	12,4801771	kN	2,52414155	0,00372948
S_2	=	13,6883545	kN	2,61654543	0,00098184
S_3	=	11,8120765	kN	2,46912244	0,01347656
S_4	=	14,6155436	kN	2,68208559	0,00938468
S_5	=	13,9316081	kN	2,63416022	0,00239602
Mittelwert		**13,305552**	**kN**	**Summe**	**0,02996859**
				2,58521105	
m_y	=	2,58521105			
s_s	=	0,08655719		Anzahl Versuche	
k_n	=	2,33		5	
P_{Rk}	=	10,84 kN			
P_{Rd}	=	8,67 kN			



4.3 6.0x80 mm spax screw; not pre-drilled

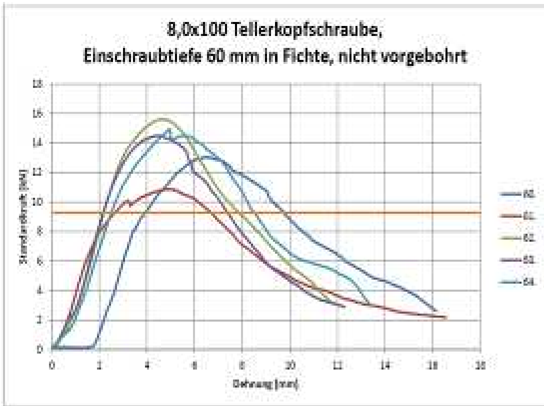
		x_i		$\ln x_i$	
S_1	=	11,1625893	kN	2,41256794	0,00304693
S_2	=	9,25075854	kN	2,22470555	0,01759957
S_3	=	12,3740974	kN	2,51560537	0,02503877
S_4	=	10,6777795	kN	2,3681649	0,00011655
S_5	=	9,63884082	kN	2,26580085	0,00838471
Mittelwert		**10,6208131**	**kN**	**Summe**	**0,05418654**
				2,35736892	
m_y	=	2,35736892			
s_s	=	0,11639001		Anzahl Versuche	
k_n	=	2,33		5	
P_{Rk}	=	8,05 kN			
P_{Rd}	=	6,44 kN			



4.4 8.0x100 mm wafer-head screw, not pre-drilled

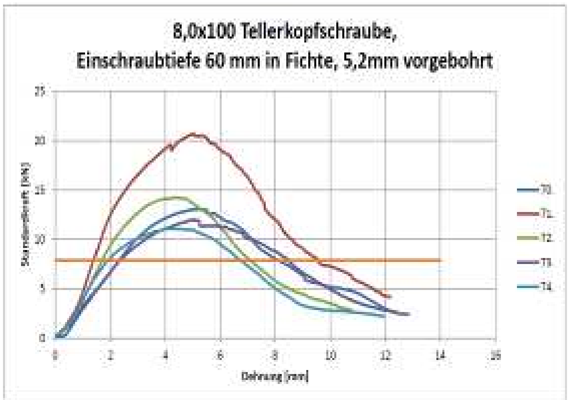
Statistische Auswertung nach EC1 Anhang D

		x_i		$\ln x_i$	
S_1	=	13,0308859	kN	2,56732238	0,00070446
S_2	=	10,8715289	kN	2,38614734	0,04314622
S_3	=	15,6154539	kN	2,74826106	0,02383844
S_4	=	14,4938638	kN	2,67372537	0,00637783
S_5	=		kN		
Mittelwert		**13,5029331**	**kN**	**Summe**	**0,07406696**
				2,59386404	
m_y	=	2,59386404			
s_s	=	0,15712729		Anzahl Versuche	
k_n	=	2,33		5	
P_{Rk}	=	9,28 kN			
P_{Rd}	=	7,42 kN			



4.5 8.0x100 mm wafer-head screw; 5.2mm pre-drilled

		x_i		$\ln x_i$	
S_1	=	13,0329324	kN	2,56747941	0,00378785
S_2	=	20,7221318	kN	3,0312023	0,16174664
S_3	=	14,2564333	kN	2,65720826	0,0007943
S_4	=	11,9769731	kN	2,4829859	0,0213274
S_5	=	11,0922732	kN	2,40624876	0,04962922
Mittelwert		**14,2161488**	**kN**	**Summe**	**0,23728541**
				2,62902493	
m_y	=	2,62902493			
s_s	=	0,24355975		Anzahl Versuche	
k_n	=	2,33		5	
P_{Rk}	=	7,86 kN			
P_{Rd}	=	6,29 kN			



For the determination of the rated value for the structural analysis, the characteristic load-bearing capacity has to be divided by the partial safety factor for failure by breakage $\gamma_V = 1.25$.

		P_{RK}	P_{RD}
4.1	6,0x90mm Din 571, nicht vorgebohrt	8,59 KN	6,87 KN
4.2	6,0x90mm Din 571, 4mm vorgebohrt	10,84 KN	8,67 KN
4.3	6,0x80mm Spaxschraube, nicht vorgebohrt	8,05 KN	6,44 KN
4.4	8,0x100mm Tellerkopfschraube, nicht vorgebohrt	9,28 KN	7,42 KN
4.5	8,0x100mm Tellerkopfschraube, 5,2mm vorgebohrt	7,86 KN	6,29 KN

The values that were determined in the test series always correspond to one pair of screws. For the structural analysis of a roof hook for the transmission of the bending moment, only the value of one screw may be assumed. It is an essential precondition that the rafter is hit precisely. Reduced edge distances result in a reduction of the tolerable pull-out forces. If there are closed battens, the correct locating of the rafter is of prime importance.

5. Summary

The subject of the present test report is the documentation and evaluation of pull-out tests with different screws and in different mounting conditions for the fastening of roof hooks on spruce wood rafters of the quality class S10.

Within the framework of the test schedule, 5 test bodies were tested under tensile loads that arise from uplifting wind suction loads and characteristic parameters were deducted on the basis of a statistical evaluation according to DIN EN 1990 (attachment D). In the course of the tests, a uniform failure criterion which was the breaking out of the screws off the wood could be observed.

Haag, August 3, 2011

Test set-up and carrying out of the test:
Dieter Fluhrer, Dipl.Ing. (FH)