The influence of moisture content variation on the withdrawal capacity of self-tapping screws

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Due to high axial load-bearing capacity and economical application without pre-drilling, self-tapping screws are widely used in modern timber constructions nowadays. Their withdrawal behaviour, as one mechanism to be verified according to *EN 1995-1-1* (2004), is discernibly influenced by the timber member and its moisture content. In case of increase of moisture content above 12 %, test results indicate a significant decrease in withdrawal capacity, which is actually not considered in design procedure. In our paper, we thus concentrate on these experimental studies, carried out in the frame of two research projects. Furthermore, we discuss two models developed for design procedure as well as for data assessment covering a large bandwidth of moisture content and compare them with results from previous investigations.

Keywords: Withdrawal capacity, axially loaded, self-tapping screws, moisture content variation

Introduction

Modern self-tapping screws are multifunctional applicable fasteners in timber engineering nowadays. In major cases, they get primary axially loaded activating their high bearing capacity reached at small deformations with minor possibility for load redistribution. Following the design procedure concerning those axial load conditions, as given in *EN 1995-1-1* (2004), two main failure modes have to be verified: steel failure in tension (i) and withdrawal failure (ii). Thereby, failure mode (ii) represents the maximum reachable resistance achieved by the composite model "timber-screw" and is thus also influenced by climatic changes of relative humidity and temperature leading to a variation of the timber member its moisture content u.

With special focus on a moisture content of 12 % as reference, values of timber strength (approx. 2-4 % per % of moisture content difference Δu) and stiffness (approx. 1-3 % per % of moisture content difference Δu) parameters decrease more or less linearly with increasing moisture content u till fibre saturation point (fsp, $u \approx 28$ % for Norway spruce) is reached. A variation of moisture content above this point does not affect those properties significantly; a constant plateau can thus be assumed. This phenomenon, a significant decrease beneath and insignificant variations above fsp, is well known for timber properties in general and described in the literature (*see e. g. Kollmann,* 1951; *Kollmann,* 1959; *Gerhards,* 1980; *Rammer and McLean,* 1996; *Keunecke et al.,* 2007; *Horvath et al.,* 2008).

In contrast to that, the relation between withdrawal capacity and moisture content, especially of modern self-tapping timber screws, has not been investigated extensively. Tab. 1 summarizes this relationship for moisture contents of $u \geq 10$ % determined by *Görlacher* (1990), *Jablonkay* (1999), *Pirnbacher et al.* (2009) and *Hübner* (2013) for different wood species and angles α of screw axis to grain direction. It is worth to be noted, that test procedure of all investigations was done as follows: preparation of specimen – climatic conditioning till achievement of planned moisture content – inserting the screw – withdrawal test. Thus, this method simulates the case that moisture content of timber members will not change after assembling, which is not always applicable in practical matter. Motivated by this circumstance, the small range of moisture content tested and the marked deviation observed on withdrawal capacity reduction we focus in our paper on the results of an extensive test program carried out between the years 2011-2013. As shown in section "Materials, methods and test results", main parameters such as the angle α, the lay-up of the timber product and the way of conditioning have been varied considering a large bandwidth of moisture content levels.

Tab. 1: Literature observations regarding the behaviour of withdrawal strength f_{ax} in dependence of moisture content variation Δu

Tab. 1: Beobachtungen hinsichtlich des Verhaltens der Ausziehfestigkeit f_{ax} bei Holzfeuchtevariation Δu

Reference	Species	Timber product	Moisture content levels (number and values)	Behaviour of withdrawal strength f_{ax} (observed or proposed decrease)
Görlacher (1990)	Spruce	ST	3: 11.5 %, 16 % 22 %	~ 2.7 %/ 1 % Δu
Jablonkay (1999)	Spruce, douglas fir, beech	ST	2: 10 %, 20 %	~ 3.3 %/ 1 % moisture content u (α = 90°) ~ 4.5 %/ 1 % Δu (α = 0°) (both for spruce)
Pirnbacher et al. (2009)	Spruce	ST, GLT	4: 0 %, 9 %, 14 %, 19 %	~ 0.7 %/ 1 % Δu (α = 0°/ 90°)
Hübner (2013)	Ash	GLT	2: 11 %, 28 %	~ 2.4 %/ 1 % Δu (α = 90°) ~ 2.7 %/ 1 % Δu (α = 0°)

Results are the basis for two model approaches not only developed for use in design procedure but also for data assessment of laboratory as well as *in-situ* tests, see section "Modelling". In addition, test data of *Pirnbacher et al.* (2009) have been reviewed regarding the measuring device used and analysed again leading to results well in-line with those presented in section "Materials, methods and test results".

Materials, methods and test results

General remarks

The test program was carried out in two main steps. The first step (see section "Test series in solid timber") aimed to investigate withdrawal behaviour in reference material solid timber for a large bandwidth of moisture content u while the second especially focused on three specific moisture content levels for crosswise laminated products such as CLT, see section "Test series in cross laminated timber". All tests were performed under "push-pull" load conditions on two test rigs Proceq Z-25FS (concrete adhesion tester) and LIGNUM-UNI-275 (All-round-Line testing machine by manufacturer Zwick GmbH & Co. KG) following the regulations given in *EN 1382* (1999). When tests were finished, local density has been determined by measuring physical dimensions as well as moisture content u by performing oven dry method. In addition, samples were cut in the middle and observed regarding knots influencing the axial load-bearing behaviour and – if they had – thus marked as outliers. It has to be noted that (i) all tests failed by withdrawal and (ii) deviating from *EN 1382* (1999), withdrawal strength f_{ax} has been determined as follows:

$$f_{ax} = \frac{F_{max}}{d \cdot l_p \cdot \pi} \qquad (1)$$

where F_{max} is the maximum force reached per test, d the thread diameter and l_p the inserted threaded part of the screw (including its tip if not fully penetrated through the specimen).

Conditioning of test specimen

As mentioned before, one main impulse to perform this test program was the way test specimens were conditioned in the literature sources listed up. In contrast, conditioning of test specimen described in section "Test series in solid timber" and section "Test series in cross laminated timber" was done differently: preparation of specimen – climatic conditioning till reference moisture content of 12 % was reached – inserting the screw – climatic conditioning till target moisture content u was reached – withdrawal test. Furthermore, one control group named "18pc" (at u = 18 %) has been performed the way mentioned in section "Introduction", see Tab. 2.

Test series in solid timber

The dimensions of solid timber test specimen out of Norway spruce (*Picea abies*) as well as the location of the partially threated diameter 6 mm screw (*ETA-12/0373*, 2012) used for this main test program are illustrated in Fig. 1. An overview of realized moisture content u_{mean}, density $\rho_{12,mean}$ (for u = 12 %) and withdrawal strength $f_{ax,mean}$ reached for the series is given in

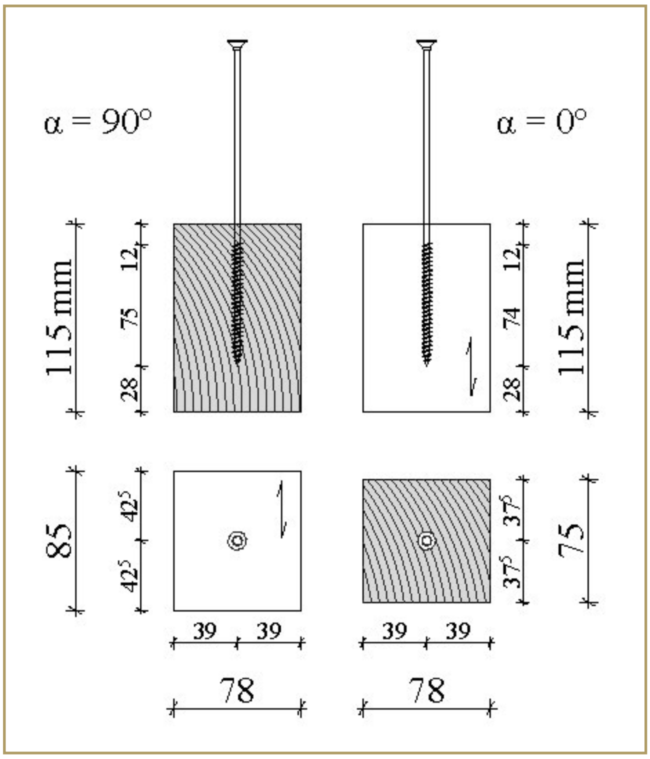

Fig. 1: Dimension of solid timber test specimen and location of screws

Abb. 1: Abmessungen der Vollholzprobekörper und Schraubenanordnung

Tab. 2: Values of moisture content u_{mean}, density $\rho_{12,mean}$ and withdrawal strength $f_{ax,mean}$ for angle α of screw axis to grain direction of 0° and 90° in solid timber

Tab. 2: Werte der Holzfeuchte u_{mean}, Rohdichte $\rho_{12,mean}$ und Ausziehfestigkeit $f_{ax,mean}$ für Winkel α zwischen Schraubenachse und Faserrichtung von 0° und 90° in Vollholz

Diameter	α	Group	n	Moisture content		Density at u = 12 %		Withdrawal strength	
				u_{mean}	CoV [u]	$\rho_{12,mean}$	CoV [ρ_{12}]	$f_{ax,mean}$	CoV [f_{ax}]
[mm]	[°]	[-]	[-]	[%]	[%]	[kg/m³]	[%]	[N/mm²]	[%]
6	90*	00p	45	0.36	24.20	415.0	10.70	6.13	16.30
		07p	33	7.68	2.91	413.2	7.51	7.08	10.30
		09p	34	10.10	4.08	409.4	6.99	6.96	10.80
		12p	37	12.20	2.30	415.3	8.63	6.99	13.60
		15p	33	15.50	2.96	409.7	8.12	6.10	13.70
		18p	37	18.20	5.53	412.9	8.76	5.59	10.90
		20p	35	19.70	5.60	410.7	9.31	5.37	9.82
	90**	18pc	21	18.00	8.73	418.2	11.80	5.70	12.00
	0**	00p	51	0.15	27.60	433.3	12.20	5.38	19.50
		06p	52	5.40	5.65	438.2	12.90	5.92	22.50
		09p	50	9.24	3.80	433.1	12.20	5.83	25.10
		12p	39	11.30	3.12	428.0	12.20	5.63	20.80
		15p	50	15.50	4.54	430.0	12.00	4.82	24.10
		18p	50	18.00	5.13	429.0	11.70	4.17	26.50
		21p	51	21.70	5.55	433.6	12.10	3.80	21.50

* Carried out on Proceq Z-25FS
** Carried out on LIGNUM-UNI-275

Tab. 2. Additionally, Fig. 2 shows withdrawal strength f_{ax} in dependence of moisture content u and angle α of screw axis to grain direction. With regard to these results some main principles are worth to be mentioned.
Firstly, mean densities of the series do not differ significantly, density correction of withdrawal strength was thus not necessary. Secondly and independently from the angle of load (screw) axis to grain direction, the behaviour of withdrawal strength in dependence of moisture content u can be qualitatively divided up into three main parts: (i) from moisture content u of 0 to ~ 8 %, the withdrawal strength f_{ax} increases with increasing u, (ii) a more or less constant plateau between moisture content u of 8 % and 12 % can be observed, and (iii) from 12 to ~ 20 %, the withdrawal strength f_{ax} significantly decreases with increasing moisture content u. Thirdly, both groups "18p" (conditioning after inserting the screw) and "18pc"

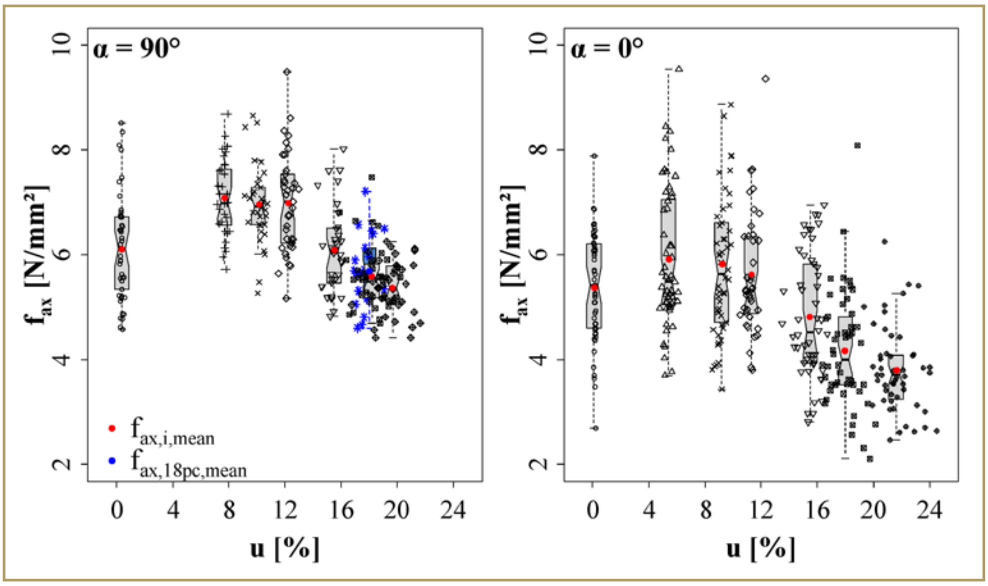

Fig. 2: Withdrawal strength in dependence of moisture content in solid timber (left: α = 90°; right: α = 0°)
Abb. 2: Ausziehfestigkeit in Abhängigkeit der Holzfeuchte in Vollholz (links: α = 90°; rechts: α = 0°)

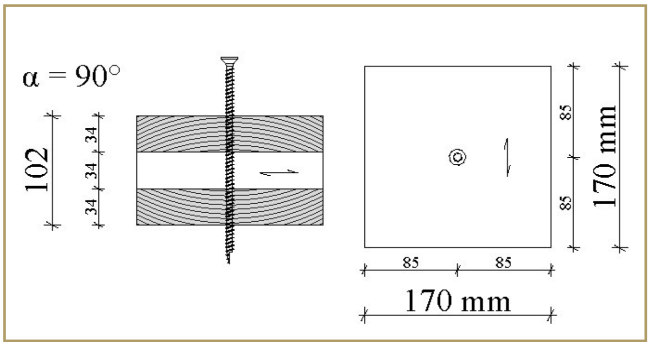

Fig. 3: Dimension of CLT test specimen and location of screws

Abb. 3: Abmessungen der Brettsperrholzprobekörper und Schraubenanordnung

(conditioning before inserting the screw) for the angle α of 90° have been tested for significance deviation of mean and median values using Student's t-test (lognormal distribution of withdrawal strength f_{ax} was assumed) and Wilcoxon-Mann-Whitney test. P-values result to 0.55 and 0.42 respectively, indicating that both groups do not differ significantly.

Test series in cross laminated timber

With the goal to understand the influence of moisture content variation on the withdrawal capacity of self-tapping screws in timber products with crosswise layer orientation, it is presented herein a small part of results obtained by an experimental campaign focused on this topic. Hereby, withdrawal capacity of self-tapping screws inserted perpendicular to the side face of three layered CLT test specimen (α = 90°) had been determined. As shown in Fig. 3 and deviating from regulations given in *EN 1382* (1999), the fully threated diameter 8 mm screw (*ETA-12/0373,* 2012) used in this series was penetrated through the whole test specimen in order to avoid tip caused influences on layer orientation. As mentioned in section "General remarks", specific moisture contents tested were: 8 %, 12 % and 18 %. Tab. 3 and Fig. 4 show the results of this test campaign in dependence of moisture content u. As expected, and similar to the test series carried out in solid timber, more or less constant values of the withdrawal strength f_{ax} for moisture content between 8 % and 12 % as well as a decrease for moisture content u ≥ 12 % can be observed. Compared to the results shown in section "Test series in solid timber", a smaller ratio between withdrawal strength $f_{ax,12}$ and $f_{ax,18}$ is given. In section "Modelling" this fact will be treated more in detail.

Review of test data from *Pirnbacher et al.* (2009)

As shown in sections "Test series in solid timber" and "Test series in cross laminated timber", tests results in solid timber indicate significant decrease of withdrawal strength f_{ax} with increasing moisture content u (for u ≥ 12 %), which thus are in contrast to results published by *Pirnbacher et al.* (2009). This fact led to reassessment of the test data used by *Pirnbacher et al.* (2009) for statistical analysis. In general, their experimental program contained withdrawal tests in solid timber as well as in GLT for moisture contents u of 0 %, 9 %, 14 % and 19 % (9 % case has only been carried out in ST) and angle α of screw axis to grain direction of 0° and 90°. All tests, except the subseries with moisture content of 19 % (carried out on LIGNUM-UNI-275), were performed on the test rig Proceq Z-25FS. In contrast to the tests described in section "Test series in solid timber", where some subseries were also carried out with this setup, data reassessment showed that, for a certain number of tests, maximum forces per test, $F_{max,i}$ were not correctly determined. In such cases, a maximum reachable deformation $w_{max,setup}$ limited by the test rig led to determination of reduced values of F_{max}, see Fig. 5. This measurement error was only found for test results with moisture contents of 9 % and 14 %, where, compared to 0 % and 19 %, higher withdrawal resistances and thus higher axial deformations are expected.
Consequently, both subgroups have to be seen as right censored data sets being evaluated using maximum-likelihood estimation (rcMLE). Assuming lognormal-distributed test results, $X = F_{max,i} \sim 2pLND\,(x|\theta)$, parameters $\theta = (\mu_y, \sigma_y)$ are estimated by maximization the log-likelihood function.

$$ln\left[L\left(\hat{\theta}\middle|x_i\right)\right] = \max_{\theta}\left[ln\left[L\left(\theta\middle|x_i\right)\right]\right] \text{ with}$$
$$L\left(\hat{\theta}\middle|x_i\right) = \prod_{i=1}^{n} f_{x_i}\left(x_i\middle|\theta\right)^{d_i} \cdot \left[1 - F_{x_i}\left(x_i\middle|\theta\right)\right]^{1-d_i} \qquad (2)$$

where d_i differs between 1 and 0, which includes the information whether the maximum forces per test F_{max} has been reached or not. Fig. 6 shows both uncorrected and corrected (estimated

Tab. 3: Values of moisture content u_{mean}, density $\rho_{12,mean}$ and withdrawal strength $f_{ax,mean}$, angle α of screw axis to grain direction of 90° in CLT (side face)

Tab. 3: Werte der Holzfeuchte u_{mean}, Rohdichte $\rho_{12,mean}$ und Ausziehfestigkeit $f_{ax,mean}$ für Winkel α zwischen Schraubenachse und Faserrichtung von 90° in Brettsperrholz (Seitenfläche)

Diameter	α	Group	n	Moisture content		Density at u = 12 %		Withdrawal strength	
				u_{mean}	CoV [u]	$\rho_{12,mean}$	CoV [ρ_{12}]	$f_{ax,mean}$	CoV [f_{ax}]
[mm]	[°]	[-]	[-]	[%]	[%]	[kg/m³]	[%]	[N/mm²]	[%]
8	90*	08p	10	8.54	4.11	465.6	12.1	6.54	10.50
		12p	10	11.70	5.95	466.6	12.6	6.42	10.20
		18p	9	17.90	2.38	462.6	10.2	5.72	5.28

* Carried out on LIGNUM-UNI-275

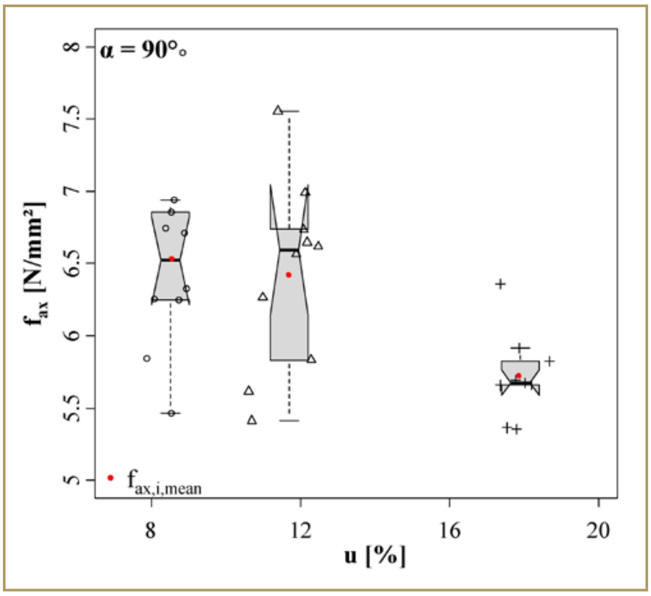

Fig. 4: Withdrawal strength in dependence of moisture content in CLT (side face, α = 90°)

Abb. 4: Ausziehfestigkeit in Abhängigkeit der Holzfeuchte in Brettsperrholz (Seitenfläche, α = 90°)

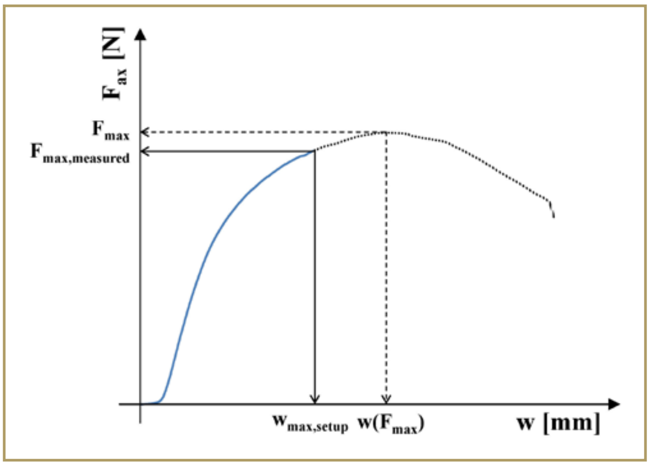

Fig. 5: Measurement error of withdrawal capacity in the force-deformation relationship

Abb. 5: Messfehler des Ausziehwiderstandes im Kraft-Verschiebungs-Diagramm

mean values by rcMLE) results of the series carried out in ST with angle α of 90° representatively. Especially for moisture contents of u ≥12 %, the ratio of decrease of withdrawal capacity in dependence of the moisture content significantly increases as result of data correction. In Tab. 4, the relative difference of withdrawal strength f_{ax} between moisture contents of 14 % and 19 % (referenced on $f_{ax,14,mean,i}$) is given for all series carried out by *Pirnbacher et al.* (2009).

Modelling

The modelling of the withdrawal behaviour in dependence of moisture content variation described in section "Bilinear model approach for moisture contents between 8 % and 20 %" and section "Nonlinear continuous function" pursued two main objectives: development of (i) a simple bilinear model approach for moisture contents between 8 % and 20 % and (ii) a continuous function for the whole bandwidth of moisture content observed. To provide both models independently from absolute values of withdrawal strength, we referenced each data set (ST, α = 0° and 90° and CLT, α = 90°) by the mean value of their reference moisture content group related (u = 12 %, $f_{ax,12,mean,i}$).

Bilinear model approach for moisture contents between 8 % and 20 %

As shown in sections "Test series in solid timber" and "Test series in cross laminated timber", only minor (and insignificant) differences of withdrawal strength f_{ax} have been observed for moisture contents between 8 % and 12 %, leading to the recommendation of no moisture content related correction for this range (k_{mc} = 1.00). In contrast to that, the situation for moisture contents u ≥ 12 %: Here, the reduction coefficient k_{mc} as inclination of a linear model describing the decrease of withdrawal strength f_{ax} for moisture contents between 12 % and 20 % has been determined by the method of least squares. Of course, hereby only test series with (nominal) moisture content larger than or equal to 12 % have been considered. As result, Eq. 3 describes this bilinear relationship, see

$$\eta_u = \frac{f_{ax,u}}{f_{ax,12}} = \begin{cases} 1.00 & \text{for } 8\% \le u \le 12\% \\ 1.00 - k_{mc} \cdot (u - 12) & \text{for } 12\% < u \le 20\% \end{cases} \qquad (3)$$

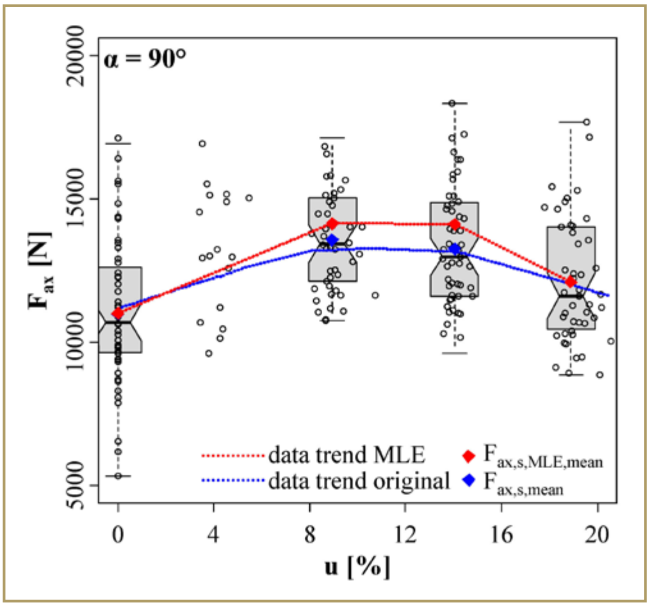

Fig. 6: Comparison of results from *Pirnbacher et al.* (2009) with corrected values (solid timber, α = 90°)

Abb. 6: Vergleich der Ergebnisse von Pirnbacher et al. (2009) mit den korrigierten Werten (Vollholz, α = 90°)

Tab. 4: Decrease of withdrawal strength f_{ax} with increasing moisture content (u = 14-19 %)

Tab. 4: Abnahme der Ausziehfestigkeit f_{ax} bei steigender Holzfeuchte (u = 14-19 %)

Group	α	Behaviour of withdrawal strength f_{ax} (between moisture content u of 14 % and 19 %)
Solid timber	0°	~ 2.7 %/ 1 % Δu
	90°	~ 2.9 %/ 1 % Δu
GLT	0°	~ 2.7 %/ 1 % Δu
	90°	~ 2.5 %/ 1 % Δu

with a reduction coefficient k_{mc} of 0.036 and 0.031 for ST, angle α of screw axis to grain direction of 0° and 90° (or k_{mc} of 0.034 independent from α in a more simplified form) and 0.017 for CLT, angle α of 90°. As mentioned in section "Test series in cross laminated timber", the determined inclination coefficient is about two times smaller for CLT compared to ST. With regard to the relatively small number of tests (see Tab. 3), this difference still has to be studied. One reason therefore may be the positive effect of crosswise lamination.

Nonlinear continuous function

The assessment of laboratory tests as well as *in-situ* observations, where moisture contents are lower than 8 % or higher than 20 % may also appear requires the description of their influence on withdrawal strength f_{ax} with a steady and continuous function. Hence, we apply a polynomial approach developed by *Glos* (1978) (originally for the description of GLT compressive strength behaviour), as given in Eq. 4 (parameters are renamed):

$$\eta_u = \frac{f_{ax,u}}{f_{ax,12}} = \eta_0 + \frac{u + k_1 \cdot u^N}{k_2 + k_3 \cdot u + k_4 \cdot u^N} \quad \text{for } 0\,\% < u \le 20\,\% \tag{4}$$

with

$$k_1 = \frac{\eta_{fin}}{(N-1) \cdot k_{mc,start} \cdot u_{mean,pl}^N \cdot \left(1 - \frac{\eta_{fin}}{\eta_{pl}}\right)} \tag{5}$$

$$k_2 = \frac{1}{k_{mc,start}} \tag{6}$$

$$k_3 = \frac{1}{\eta_{pl}} - \frac{N}{N-1} \cdot \frac{1}{k_{mc,start} \cdot u_{mean,pl}} \tag{7}$$

$$k_4 = \frac{k_1}{\eta_{fin}} \tag{8}$$

$$\eta_0 = \frac{1}{n} \cdot \sum_{j=1}^{n} \frac{f_{ax,0,j}}{f_{ax,12,mean,i}} \tag{9}$$

$$\eta_{pl} = \frac{1}{n} \cdot \sum_{j=1}^{n} \frac{f_{ax,pl,j}}{f_{ax,12,mean,i}} \tag{10}$$

Hereby, $k_{mc,start}$ is the inclination parameter for referenced f_{ax} values between moisture contents of 0 % and 8 %, $u_{mean,pl}$ the mean moisture content of test series between 8 % and 12 % ("plateau values"), η_0 and η_{pl} the referenced mean values of withdrawal strength related to 0 % and $u_{mean,pl}$ as well as η_{fin} the referenced limit at fibre saturation point and N a non-dimensional fitting exponent. With regard to the scope of moisture contents tested (u = 0-20 %), the reference limit η_{fin} as only parameter remaining had to be determined by Eq. 3. This extrapolation bases on the assumption of a linear decrease of withdrawal strength f_{ax} till fibre saturation point fsp is reached, which is thus expected to be similar to the behaviour of shear strength and stiffness (*see Keunecke et al.,* 2007 *and Horvath et al.,* 2008). In Tab. 5 all model parameters determined are given for angles α of 0° and 90° and also independently from this angle α of screw axis to grain direction.

Tab. 5: Input parameters of the nonlinear model

Tab. 5: Eingangsparameter des nichtlinearen Modells

α	η_0	k_1	k_2	k_3	k_4	N
[°]	[-]	[-]	[-]	[-]	[-]	[-]
0	0.96	-2.34 * 10^{-6}	53.6	5.44	4.36 * 10^{-6}	5.94
90	0.88	-3.42 * 10^{-6}	54.8	1.37	9.13 * 10^{-6}	5.50
both	0.92	-9.13 * 10^{-6}	55.5	1.99	1.92 * 10^{-5}	5.30

Comparison with test results from similar studies

In Fig. 7, the deviation of referenced mean values ($\eta_{u,mean,i}$) of test results as well as from literature sources discussed in section "Introduction" to the nonlinear model curves (Eq. 4) is shown. Hereby, data from *Jablonkay* (1999) (only Norway spruce) and *Hübner* (2013) (ash) has been referenced by the mean values of their test series with moisture contents u of 10 % and 11.5 % ("plateau series"), while in case of the (corrected) data from *Pirnbacher et al.* (2009) this was done considering an additional test program carried out by *Gaich et al.* (2008) under the same conditions (same material, u ≈ 12 %, diameter 8 mm). With regard to this comparison, a good predictive quality of the nonlinear model approach can be attested for the vast majority of test series considered. The tendency of significantly low values of test data from *Pirnbacher et al.* (2009) at moisture contents of 0 % can be explained by the fact that the screw had been drilled into the oven dried specimen causing initial cracks before the withdrawal test was started.

Conclusion and outlook

In this paper, we showed and discussed the results of an extensive test program, which aimed to investigate the influence of moisture content variation on the withdrawal behaviour of axi-

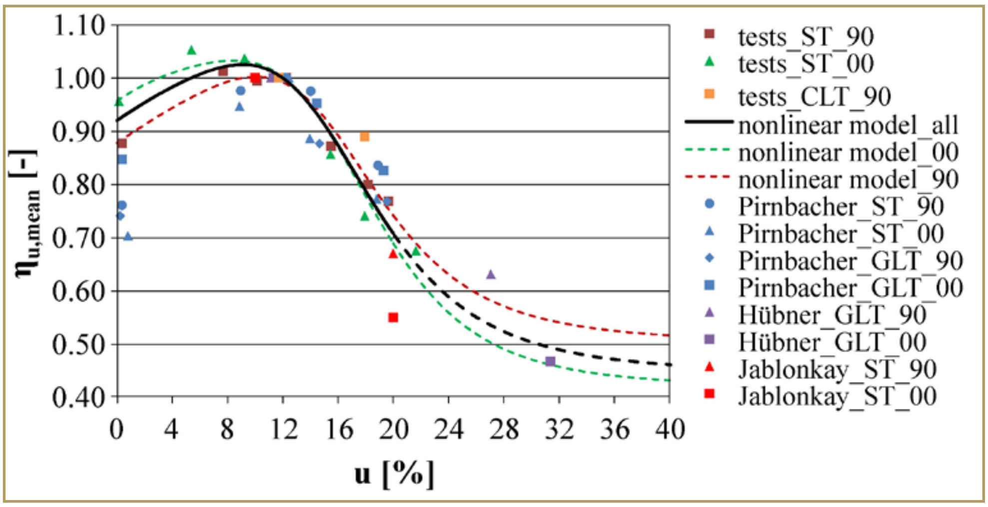

Fig. 7: Comparison of the nonlinear model approach with test results and data from literature sources (references)

Abb. 7: Vergleich des nichtlinearen Modells mit Prüfdaten und Literaturergebnissen

ally loaded self-tapping screws. With regard to the work done so far concerning this topic, we therein mainly varied moisture content u between 0 % and 20 % and the way specimen were conditioned. Consequently, we developed two model approaches: (i) a simplified bilinear approach for moisture contents between 8 % and 20 %, which covers service class 1 and 2 conditions according to *EN 1995-1-1* (2004) and can thus be considered in design process and (ii) a nonlinear continuous function, which enables data assessment for the bandwidth of moisture content observed. In this context, two essential remarks are worth to be mentioned:

First of all, a comparison, not only of model predictions with results from the literature sources discussed in the introduction but also with a control group (carried out in ST with angle $\alpha = 90°$) indicates that the way specimen are conditioned is negligible.

Furthermore, a similar behaviour of withdrawal strength f_{ax} in solid timber as well as in GLT in dependence of moisture content u, especially for 12 to 20 % can be assumed while tests of screws placed in the side face of CLT specimen ($\alpha = 90°$) show a significantly better behaviour for this special area of interest. Beside the validation of our nonlinear model for moisture contents beyond fibre saturation point as well as investigations observing the effect of cyclic variation of moisture content u between 12 % and 20 % on the withdrawal behaviour, we thus see a comparison of axially loaded self-tapping screws in unidirectional and crosswise layered timber products combined with varying moisture content u as next important step concerning this topic.

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ABSTRACT

Der Einfluss der Holzfeuchte auf den Ausziehwiderstand selbstbohrender Holzschrauben

Aufgrund ihrer hohen Tragfähigkeit bei axialer Beanspruchung sowie der wirtschaftlichen Montage ohne Vorbohren werden selbstbohrende Holzschrauben heutzutage für viele Anwendungen im modernen Ingenieurholzbau eingesetzt. Hierbei wird das Ausziehverhalten, als ein gemäß EN 1995-1-1 (2004) nachzuweisender Versagensmechanismus axial beanspruchter Holzschrauben, nicht unwesentlich vom Feuchtegehalt u des Holzbauteils beeinflusst. Speziell im Fall von Holzfeuchten größer 12 %, weisen Ergebnisse von Laboruntersuchungen auf einen signifikanten Abfall der Ausziehfestigkeit hin, welcher jedoch im derzeitigen Bemessungskonzept nicht berücksichtigt wird. Diese im Rahmen von zwei Forschungspro-jekten umgesetzten Prüfserien werden in diesem Aufsatz vorgestellt und erläutert. Zwei darauf basierende Modellansätze zur Berücksichtigung des Holzfeuchteeinflusses im Nachweisverfahren sowie zur Beurteilung von Ausziehprüfungen werden in weiterer Folge formuliert und mit Ergebnissen aus der Literatur verglichen.

Schlüsselwörter: *Ausziehfestigkeit, axiale Beanspruchung, selbstbohrende Holzschrauben, Holzfeuchtevariation*

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