SCREWS WITH CONTINUOUS THREADS IN TIMBER CONNECTIONS

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Abstract

Screws, bolts and dowels loaded perpendicular to the fastener axis are all dowel-type fasteners, whose load-carrying capacity in timber-to-timber connections may be determined based on Johansen´s yield theory (Johansen, 1949). The ultimate load of joints with dowel-type fasteners loaded perpendicular to the fastener axis is limited by the embedding strength of the timber members and the bending capacity of the fasteners.

Exploiting the withdrawal capacity of long screws with continuous threads leads to increased load-carrying capacities and hence more economic connections. In order to avoid bending of screws they are not placed perpendicular to the interface between the members to be connected but arranged under an angle of about 45°. The load is then transferred by a truss-like system where the screw is loaded in tension and the contact surface between the members in compression.
The paper presents a comparison between the test results of connections with inclined screws and fasteners loaded perpendicular to their axis and shows a number of opportunities for connections with inclined screws.

1. Introduction

Two categories of wood screws for connections in timber structures may be distinguished. Traditional wood screws show a threaded and a smooth part of the shank with different yield moments. The outer diameter of the thread generally equals the smooth shank diameter which is also the nominal diameter. The diameter of coach screws varies between 8 mm and 20 mm, the diameter of screws with countersunk or round head between 4 mm and 8 mm. The root diameter d_1 usually corresponds to 70 % of the outer diameter d.
(Ehlbeck and Ehrhardt, 1995)

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In contrast to the traditional wood screws the self-tapping wood screws manufactured with diameters up to 12 mm and lengths up to 600 mm are hardened after rolling the thread. Hardening increases the bending capacity as well as the torsion capacity. Compared to the traditional wood screws the holes for self-tapping screws generally are not pre-drilled, the bending capacity as well as the torsion capacity are greater.
With regard to the great bending capacity and particularly to the high resistance against withdrawal and pushing in, self-tapping screws are very suitable as fasteners in timber-to-timber connections.

2. Tests with self-tapping screws in timber-to-timber connections

Tests were made with specimens containing four self-tapping screws with continuous threads in each interface between the side and middle wood member, see Figure 1. The screw diameter was 7,5 mm and the screw length was 182 mm. The side and middle wood member dimensions are displayed in Figure 1.
The members were cut from glued laminated beams with 12 % moisture content. All members within a specimen had similar densities. The average density for joint members was 442 kg/m^3.
Altogether four series were carried out whereby only the angle (45° until 90°) between the screw axis and the force direction was varied.
To determine the influence of friction between the members a plastic foil was placed between the wood components for a part of the specimens.
The load-carrying capacities reached in the tests are shown in Figure 2. The solid line shows the test results for the timber-to-timber connections without a plastic foil between the wood members. The broken line shows the test results with a plastic foil. For the timber-to-timber connections with an angle of about 60° between the screw axis and the force direction, the load-carrying capacity reached a maximum value. This maximum value of the load-carrying capacity was about 53 % higher than the value for screws loaded perpendicular to the fastener axis. Due to the decreasing penetration depth of the screws in the middle wood member with decreasing angle, the load-carrying capacity for the timber-to-timber connections with an angle below 60° became smaller.
Also remarkable is the steady rise of the connection stiffness with decreasing angle between the screw axis and the grain direction. The dependency of the connection stiffness on the angle between the screw axis and the force direction is shown in Figure 3. In comparison to the timber-to-timber connections with screws loaded perpendicular to their axis, the connection with screws under an angle of about 45° reached a 12 times higher connection stiffness.
An opened specimen with an inclination of 75° between the screw axis and the force direction is shown in Figure 4. As expected, the connection failure was caused by reaching the withdrawal and bending capacity of the screw and the timber embedding strength (European Yield Models - Failure Mode 3). Timber-to-timber connections with fasteners loaded perpendicular to their axis failed due to a combined embedding/bending failure. With decreasing angle between the screw axis and the grain direction, the withdrawal component became greater.

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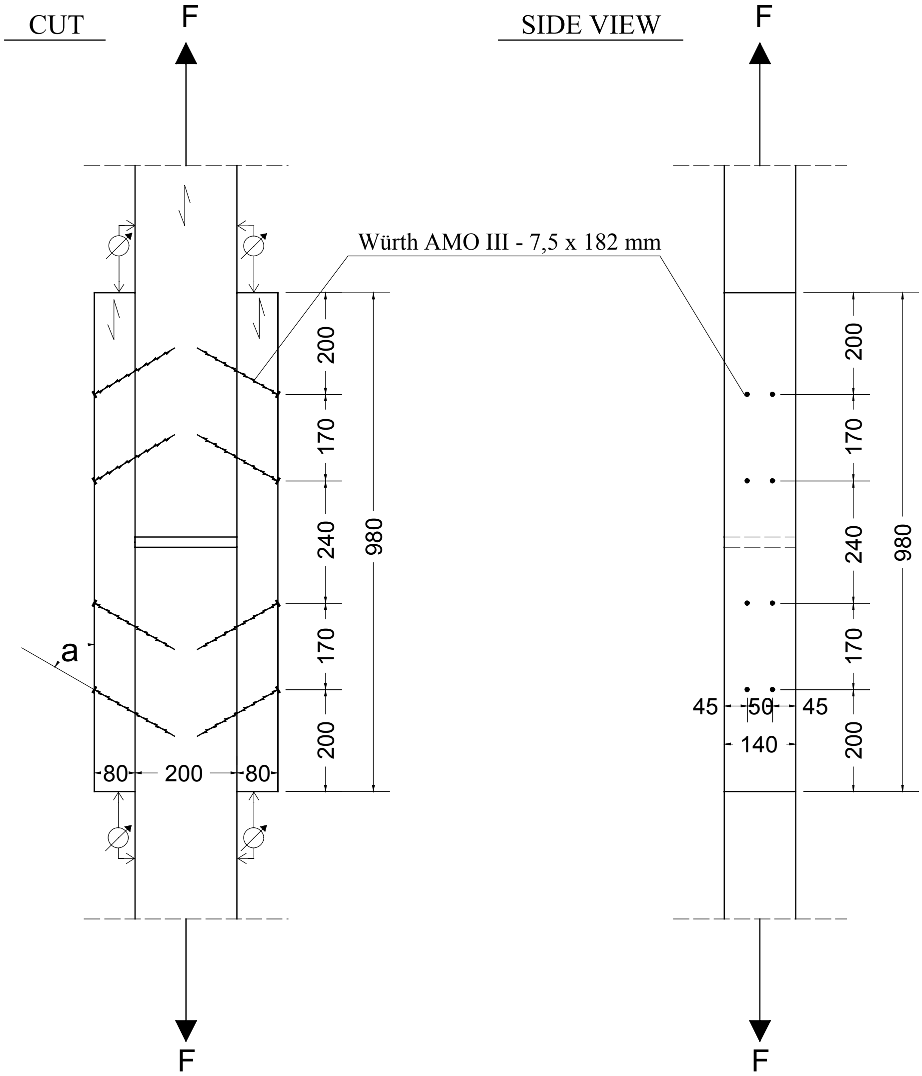

Figure 1: Timber-to-timber connection with inclined self-tapping screws

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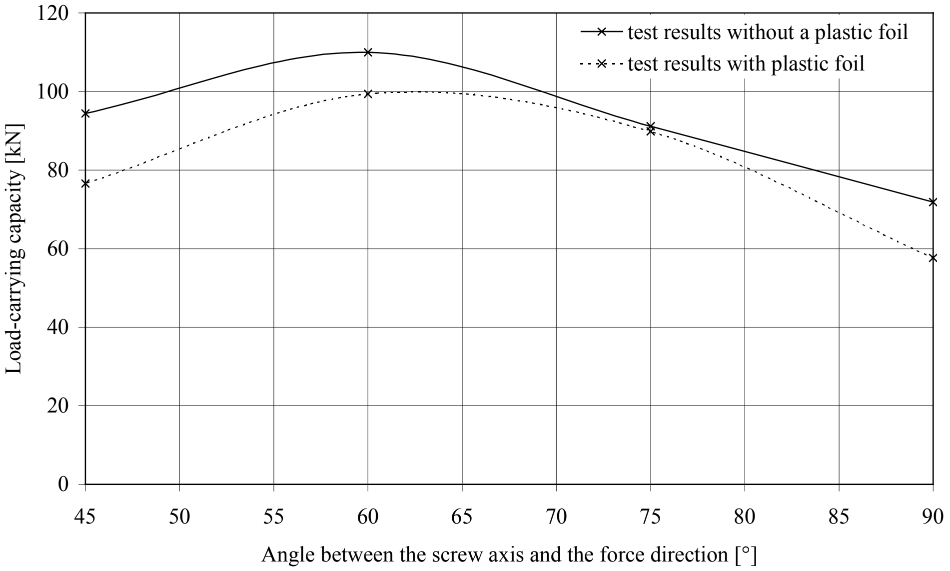

Figure 2: Load-carrying capacity in timber-to-timber connections - test results

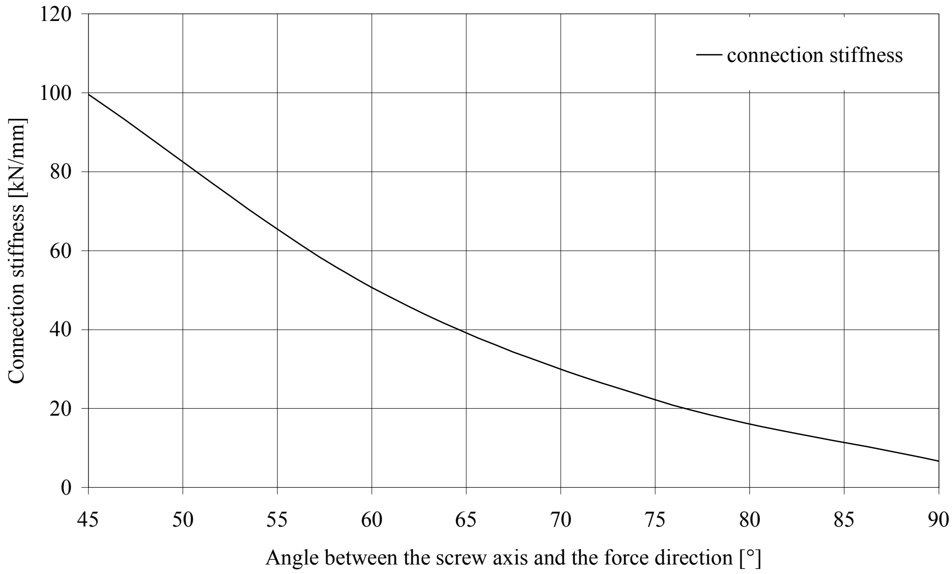

Figure 3: Connection stiffness in timber-to-timber connections - test results

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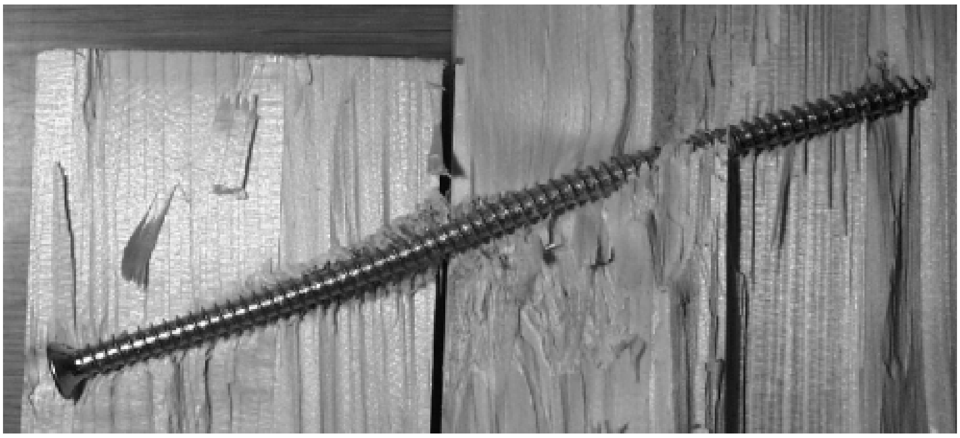

Figure 4: Sliced specimen with self-tapping screw

3. Comparison of model prediction and experimental data

Based on the foregoing discussion, it is proposed that the design of single shear screwed timber-to-timber joints be based on a modified form of Johansen´s yield theory which includes a component where the screw is loaded in tension and the contact surface between the members in compression.
The proposed equation for failure mode 3 is:

$$R_{la} = \sqrt{\frac{2 \cdot \beta}{1+\beta}} \cdot \sqrt{2 \cdot M_y \cdot d \cdot f_{h,1} \cdot \cos^2 \alpha} \qquad (1)$$

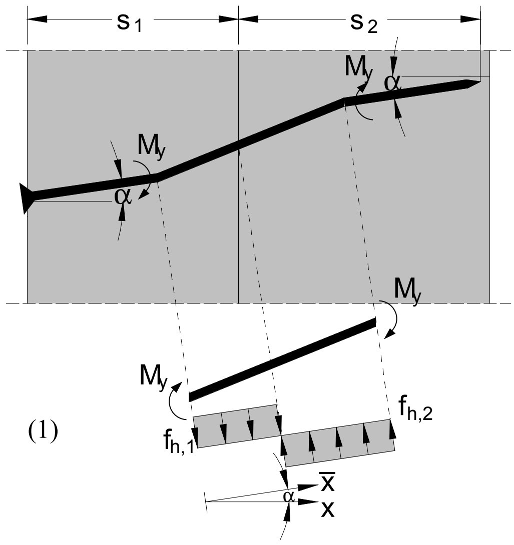

Figure 5: adjusted Mode 3

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The component R_{ax} based on the screw loaded in tension and the contact surface between the members loaded in compression (truss-like system, Figure 6):

$$R_{ax} = Z \cdot \sin\alpha = f_1 \cdot d \cdot s_{min} \cdot \tan\alpha \qquad (2)$$

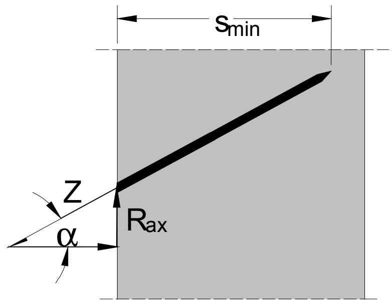

Figure 6: truss-like system

The axial resistance against withdrawal is Z. f_1 is the axial withdrawal parameter of screws in [N/mm^2] as defined in E DIN 1052.

$$R = f_1 \cdot d \cdot s_{min} \cdot \tan\alpha + \sqrt{\frac{2\cdot\beta}{1+\beta}} \cdot \sqrt{2 \cdot M_y \cdot d \cdot f_{h,1} \cdot \cos^2\alpha} \qquad s_{min} = \min\begin{Bmatrix} s_1 \\ s_2 \end{Bmatrix} \qquad (3)$$

Using parameters determined in previous tests, the load-carrying capacities according to equation (3) for timber-to-timber connections with inclined screws were calculated. The comparison of model prediction and experimental data is shown in Figure 7.
The solid line shows the test results for the timber-to-timber connections without a plastic foil between the wood members. The broken line shows the test results for connections with a plastic foil. The bold line shows the model values determined with the proposed equation.

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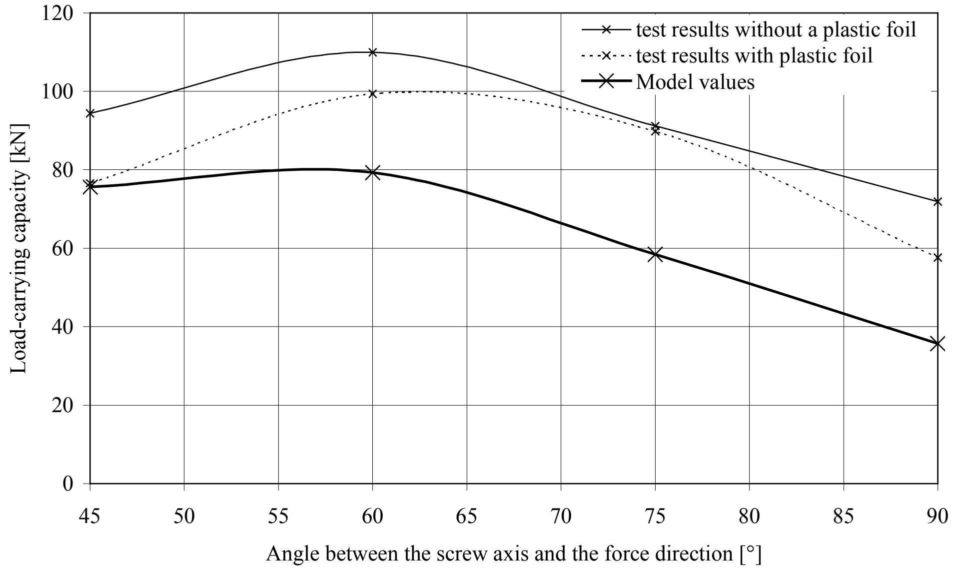

Figure 7: Comparison of model prediction and experimental data

4. Connections using inclined screws

Because of the particularly high resistance against withdrawal or pushing in, inclined self-tapping screws may be used effectively as fasteners in timber-to-timber connections. A further advantage of inclined screws is the significant increase of the connection stiffness with increasing angle (Figure 3). Figure 8 shows a schematic representation of a secondary beam - main beam connection using inclined screws.
Also here it is possible to determine the load-carrying capacity of the connection with the proposed equation for failure mode 3. The comparison of model prediction and experimental data for connections with one or two screws is shown in Figure 9. The thin line shows the test results for the secondary beam - main beam connections. The bold line shows the model values determined with the proposed equation. For connections with two screws R_{ax} is doubled.

5. Conclusions

Inclined self-tapping screws provide an opportunity for rationalisation and reduction of costs for timber-to-timber connections, particularly for design and installation. With the proposed equation (3) for failure mode 3, it is possible to determine the load-carrying

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capacities for all timber-to-timber connections with inclined screws taking into account the withdrawal and bending capacity of the screws and the timber embedding strength.

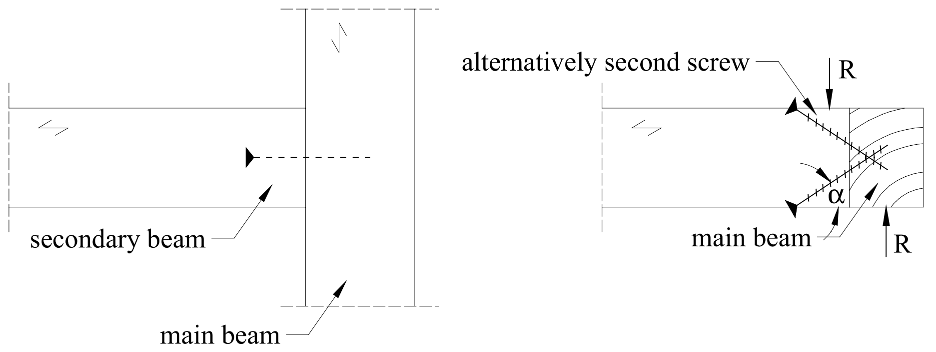

Figure 8: Schematic representation of a secondary beam - main beam connection using inclined screws

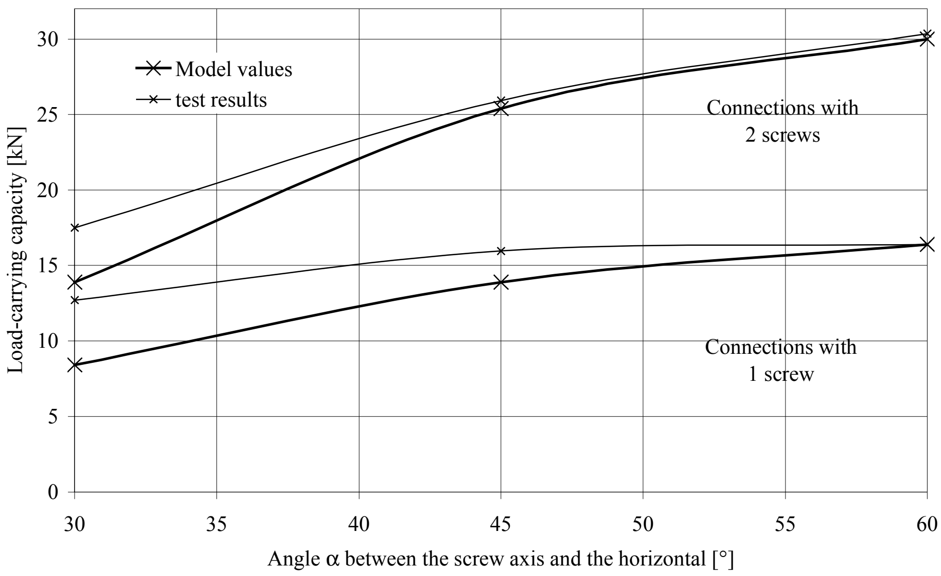

Figure 9: Comparison of model prediction and experimental data

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6. References

1. Blass, H.J., ´Verbindungen mit Nägeln und Schrauben - Bemessung nach E DIN 1052 und neuere Entwicklungen´, Ingenieurholzbau - Karlsruher Tage, September, 2000, 56-65
2. Ehlbeck, J., Ehrhardt, W., ´Screwed joints´ in ´Timber Engineering STEP 1, Basis of design, material properties, structural components and joints´ Centrum Hout, The Netherlands, ISBN 90-5645-001-8
3. Johansen, K.W., ´Theory of timber connections´ International Association of Bridge and Structural Engineering, Publication No. 9:249-262, Bern, Switzerland
4. Meierhofer, U., ´Tests on Timber Concrete Composite Structural Elements` Proceedings, CIB-W18 Timber structures, Meeting 26, Paper 26-7-5, ISSN 0945-6996

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