Pre-stressing of wood with full thread screws

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Summary

Reinforcement of modern timber and glulam structural members with full thread woodscrews is state of the art. The high axial strength of the screws and the excellent composite action between the timber and the screws are perfect to reinforce the 'weak' direction perpendicular to the grain of the timber.

In reinforced timber members the reduction of the moisture content and the subsequent shrinking deformation results in tensile stresses perpendicular to the grain near the screw because of the high axial stiffness of the screw.

In a research project, screws with a variable pitch of the thread were developed. Due to the variable thread, the screw pre-stresses the timber resulting in a compressive stress in the timber along the axis of the screw. Consequently, the strength of the reinforced timber increases and the influence of the shrinking in the area of the screw decreases.

To optimize the variation of the pitch, a numerical model was developed. In a parameter study two different thread geometries were determined that yielded the best results in terms of pretension of the timber.

FSR-sensors suited to measure a compressive force were used to determine the preload force of the screws in test series. The test series confirm the results of the numerical model. Therefore, it is possible to calculate the effect of the pretension with the model and the thread geometry can be optimized.

1. Introduction

Reinforcement of timber perpendicular to the grain with self-tapping screws is effective. The screws, e.g. in members with notches, transfer the splitting force and avoid an uncontrolled crack growth in the timber beam. The screws act like the reinforcement in concrete members: The load carrying action is not activated until a little crack occurs in the timber. Furthermore, the deformation perpendicular to the grain in high glulam

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beams resulting from changing moisture content, e.g. in heated factory buildings, is significant. Especially the shrinking deformation near reinforcing screws results in tensile stresses perpendicular to the grain because of the high axial stiffness of the screw. A compressive pre-stress hence increases the strength of the reinforced timber and decreases the influence of climatic loads.

2. Pre-stressing with screws

2.1 Screws with a variable pitch of the thread

Because of the low compressive strength of timber perpendicular to the grain the potential compressive force which can be put on the surface of timber for pre-stressing the cross section of the timber is low too. In addition, the stress spreads under the load application resulting in a lower stress level in in the middle of the cross section. For that reason, screws with variable pitch of the thread were developed. The variable pitch of the thread generates a systematic compressive stress perpendicular to the grain in the cross section of a timber element.

Figure 1 shows the geometry of the thread of a self-tapping screw with variable pitch of the thread. In areas I and III the pitch p_0 is constant. In area II the pitch p(x) changes functionally. In area II the pitch of the thread is always less than in area I and III.

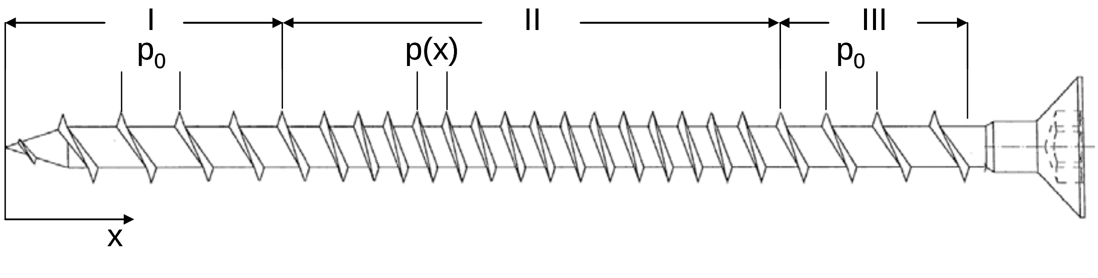

Figure 1: Self-tapping screw with a variable pitch of the thread. In areas I and III, the pitch p_0 is constant and in area II the pitch p(x) is variable.

The pitch of the thread is equal to the distance a screw covers in one turn during screwing in. A screw with a constant pitch of the thread covers the same distance along the axis by one turn. A screw with a variable pitch of the thread covers “different” distances along the axis by one turn. Because of that, restraints are generated along the axis of the screw. Those result in a compressive stress in the timber cross section. The compressive stress depends for the main part of the variation of the pitch of the thread. Figure 2 schematically shows the “deformation” of a timber cross section during the screwing of a screw with a variable pitch of the thread.

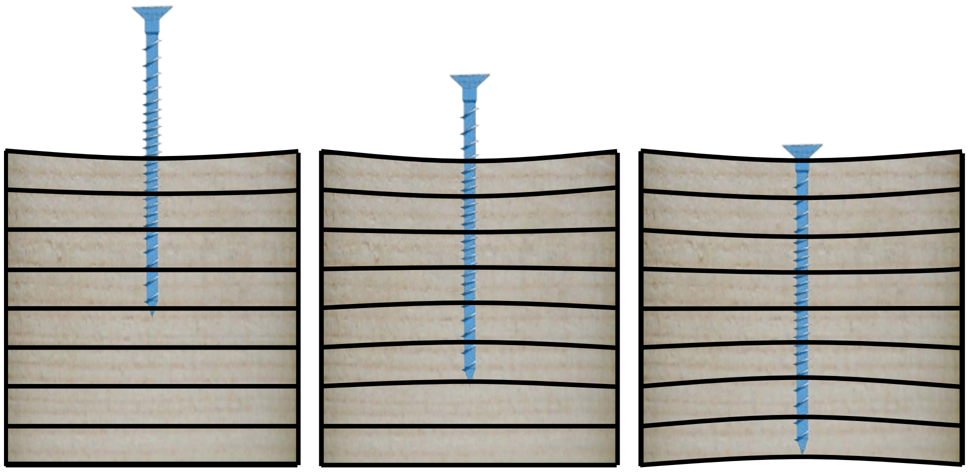

Figure 2: "Deformation" of the timber during the screwing of a screw with a variable pitch of the thread in timber.

The restraints must not pass a critical limit. Otherwise the wood matrix will be destroyed and the load transmission between the timber and the screw is no longer possible ([1],[2],[3]).

2.2 Compressive pre-stress

To optimize the variation of the pitch of the thread, a numerical model was developed. In a parameter study two different thread geometries were determined that yielded the best results in terms of pretension of the timber. Figure 3 shows the compressive stress distribution within a 200 mm high test block for a screw with variable pitch of the thread.

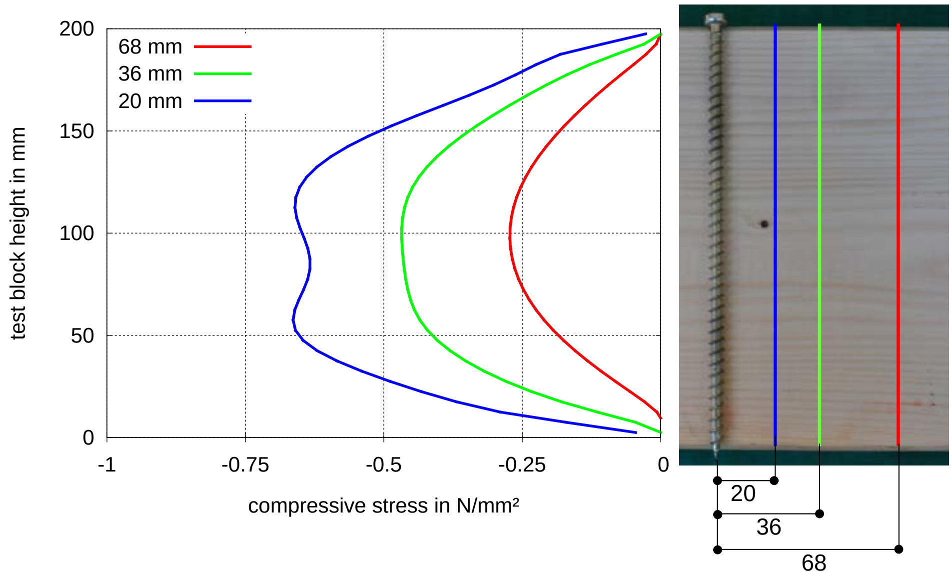

Figure 3: Calculated compressive stress over the test block height depending of the distance from the screw axis in the direction of the grain.

3. Tests

3.1 Compressive force measurement with Force-Sensing Resistor (FSR)

To measure the influence of the screw with variable pitch of the thread on the load distribution of the timber, a thin measuring element is necessary that can be inserted between two pieces of a timber test block. The Force-Sensing Resistor (FSR) is a thin measurement element that changes its electrical resistance depending on a force reaction. The FSR consists of two laminated plastic films. One film is semi-conductively covered and the other one contains two conducting finger-shaped paths gearing into each other but electrically separated. If the films are compressed, the electrical resistance decreases depending on the compression force.

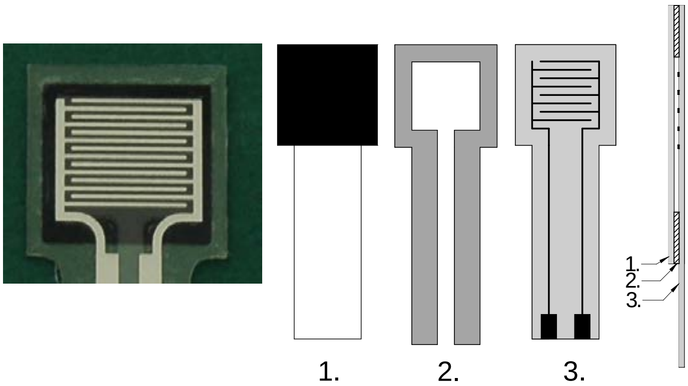

Figure 4: Picture of a FSR and the setting of a FSR: 1. film semi-conductive covered, 2. adhesive layer, 3. Film with finger-shaped electrode.

3.2 Test blocks and test configuration

To confirm the calculated compressive pre-stress, tests with glulam blocks and screws with variable pitch of the thread were performed. The test blocks had a height of 200 mm that corresponded with the length of the test screws and a base area of 160 x 160 mm². For each test block the dynamic modulus of elasticity and the density was determined. To measure the compressive force the test blocks were cut in three different heights. Figure 5 shows three test blocks with measurement heights of 50 mm, 100 mm and 150 mm.

Figure 5: Glulam test blocks for compressive force measuring in the height of 50 mm, 100 mm and 150 mm.

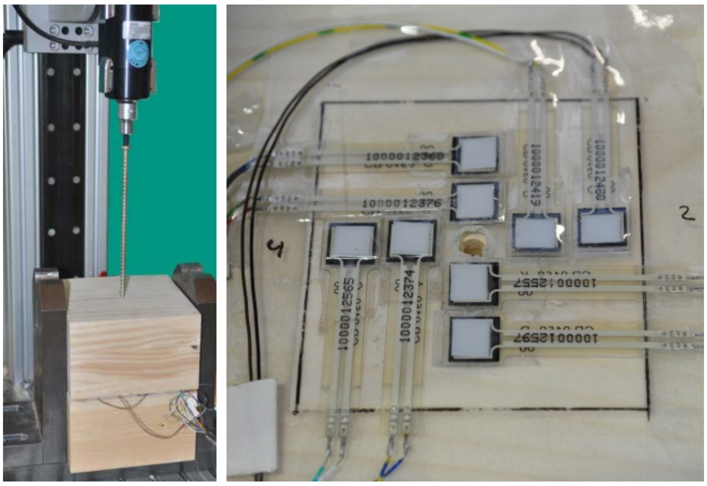

Figure 6: Test configuration.

The FSRs were fixed on a plastic film and the FSR configuration was put between the two parts of test blocks as shown in Figure 6.

The test block was placed into the hinge moment analysis system, the screw was screwed in and the compressive force was measured continuously with the FSRs.

3.3 Test results

Figure 7 shows the results of two test series with different thread geometries. Except for the values in 50 mm depth from variation 1, the measured values agree with the calculated values from the numeric model. The test series show that a preload with screws with a variable pitch of the thread is possible and the numeric model is able to calculate the effect of the pretension. Therefore, the thread geometry can be optimized for different applications of the screw.

A compressive pre-stress of -0.5 N/mm² was reached with the chosen thread geometry. Referring to the low tensile strength perpendicular to the grain, the reached pre-stress is remarkable.

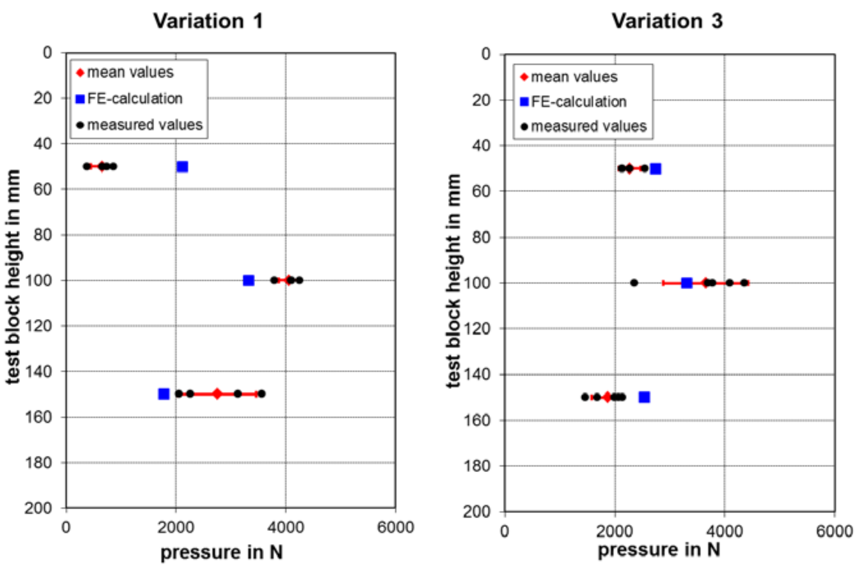

Figure 7: Test results from two different thread geometries.

4. Summary and Outlook

The test results show that screws with a variable pitch of the thread are suitable to apply a remarkable compressive pre-stress to timber elements. The numerical model can calculate the pre-stress depending on the thread geometry so that the thread geometry can be optimized.

To study the long-term behaviour of timber-members pre-stressed by means of screws further research with regard to relaxation, shrinking and swelling is needed. For this purpose, long-term tests are in progress.

References

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