EFFECTS OF CHANGES IN MOISTURE CONTENT IN REINFORCED GLULAM BEAMS

Philipp Dietsch¹, Heinrich Kreuzinger², Stefan Winter³

ABSTRACT: Reinforcement in form of screws or rods can restrict the free shrinkage or swelling of the reinforced timber beam. The objective of the project presented was to evaluate the influence of such reinforcement on the magnitude of moisture induced stresses. For this purpose, experimental studies were carried out in combination with analytical considerations on the basis of the finite-element method. Taking into account the influence of relaxation processes, the results indicate that a reduction of timber moisture content of 3 - 4 % around threaded rods, positioned perpendicular to the grain, can lead to critical stresses with respect to moisture induced cracks. In addition, a substantial mutual influence of adjacent reinforcing elements could be identified. A reduction of the distance between the reinforcing elements thus results in a lower tolerable reduction of timber moisture content around the reinforcement.

KEYWORDS: timber, glued laminated timber, reinforcement, threaded rod, screw, moisture, moisture induced stresses

1 INTRODUCTION

Changes in wood moisture content lead to changes of virtually all physical and mechanical properties (e.g. strength and stiffness properties) of wood. An additional effect of changes of the wood moisture content is the shrinkage or swelling of the material and the associated internal stresses.

The distribution of timber moisture content in the cross-section is not only dependent on the relative humidity but also on time, due to the time necessary for moisture transport by diffusion. This results in a moisture gradient, leading to shrinkage or swelling strains of different magnitude over the timber cross-section. During the drying process of a timber element, the wood material near the surface is held by the inner cross-section, comparable to an elastic foundation. This results in tensile stresses perpendicular to the grain near the surface which are counterbalanced by compressive stresses inside the cross-section due to the necessary equilibrium of stresses. If the tensile stresses locally exceed the very low tensile strength perpendicular to grain, the result will be a stress relief in form of cracks. These can reduce the load-carrying capacity of structural timber elements in e.g. shear or tension perpendicular to the grain.

If the free deformation of the cross section is prevented by holding forces, e.g. fasteners in dowel-type connections, the magnitude of the moisture induced stresses becomes dependent on the difference between the strains of the timber cross-section and the holding elements. The holding forces impede the equilibrium of tensile and compressive moisture induced stresses in the timber element. The result is stresses of higher magnitude which can result in deep shrinkage cracks. An example is fork supports with dowel-type fasteners arranged at considerable vertical distance. In the case of screws or rods positioned perpendicular or at an angle to the grain, the free deformation of the surrounding wood material is restrained due to the semi-rigid composite action between the wood material and the thread of the reinforcement, see Fig. 1. Reason is that steel features an expansion coefficient with respect to temperature changes but, in contrast to wood, not with respect to changes in moisture.

2 MECHANICAL MODEL

To describe such reinforced cross sections mechanically, a beam on elastic foundation in longitudinal direction can be used, see Fig. 1 and [1]. The stiffness of the semi-rigid composite action is represented by the embedment modulus (modulus of foundation) in longitudinal direction. In the case of a timber element under shrinkage, the result will be compressive stress trajectories in conical form. The tensile stress trajectories will subsequently align parallel to the reinforcing element, see Fig. 1.
3 EXPERIMENTS

To gain first insight into the behavior of reinforced glulam elements under shrinkage, tentative short-term experiments were carried out. These are based on the idea that, in the case of a relatively stiff composite between the reinforcement and the wood material, type and location of the induced strains have a rather small effect on the stress distribution in the glulam element. Using the mechanical model given above and assuming either exterior load (e.g. tensile force on the reinforcement) or internal stresses (e.g. restrained shrinkage), the main transfer of stresses between the steel reinforcement and the wood material will occur in the vicinity of both ends ($x = 0, x = \ell$) of the reinforcement. This means that, although the nature of the strain (shrinkage strain or strain due to externally applied tensile load) is different from one another, the stress distribution in the glulam element, as a result of the interaction between the wood and the reinforcing element, is comparable.

After this assumption was validated by means of Finite-Element-Analysis [1], experiments on real-size glulam elements, reinforced by a glued-in rod positioned perpendicular to the grain, were carried out, see Figure 2. These were realized as displacement controlled tensile tests, whereby the tensile load was applied to the reinforcement. During the tests, the strain distribution at the surface of the specimen was recorded by means of a contact-free optical measurement system. In all experiments, one large crack occurred within the inner quarters of the specimen height at local maximum strains $\varepsilon_{\text{max}} \approx 0.5\%$. A further load-increase lead to an opening of the existing crack but not to the development of additional cracks. This result is in accordance with perceptions in real structures featuring glulam beams reinforced with rods.

4 FINITE-ELEMENT ANALYSIS

The results received from the experiments were used for further analysis in a Finite-Element model. Using the stiffness values determined for the specimen, the tensile stresses perpendicular to the grain in the test specimen was determined for the load at fracture and at maximum load. Using the same model, the equivalent decrease in moisture content, causing a corresponding distribution and magnitude of tensile stresses perpendicular to the grain was determined.

5 OUTCOME

Since the experiments carried out do not allow any conclusions on long-term effects such as relaxation, extensive research on this effect, published by other authors* was drawn upon. Taking into account stress relaxation in the magnitude of 60 %, the results indicate that a reduction of timber moisture content of 3 - 4 % around threaded rods, positioned perpendicular to the grain, can lead to critical stresses with respect to moisture induced cracks. In the case of shear reinforcement with 45° inclination, the magnitude of moisture induced stresses is reduced by half while the stressed volume is reduced even more (to about 15%). For both types of arrangement, a substantial mutual influence of adjacent reinforcing elements could be identified. A reduction of the distance between the reinforcing elements thus results in a lower tolerable reduction of timber moisture content around the reinforcement.

REFERENCES


* A complete list of references with regard to the project is given in the full paper.