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Ductility aspects of reinforced and non-reinforced timber joints

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ABSTRACT

Even though brittle failure modes in timber joints may be avoided by the proper design of the connection, the use of minimum timber dimensions and minimum spacing and distances of fasteners often leads to timber splitting in the connection area. Due to the highly nonlinear behaviour of timber loaded in compression as well as the steel used for mechanical fasteners, timber joints can behave in a rather ductile manner. Ductile behaviour is preferable in timber structures.

Technical innovations regarding engineered wood products as well as fastener and steel technology led to the development of high-performance timber connections. In these high-performance connections, brittle failure modes are prevented by reinforcing the timber in the connection area perpendicular to the grain or using cross-laminated timber members. The improvement of the ductility levels is shown based on several experimental studies comparing non-reinforced to reinforced connections.

1. Introduction

The failure mechanism of a timber joint with mechanical fasteners among other things depends on the geometry of the joint and the type of fastener. Under compressive stresses, timber as a material may be loaded far over its elastic limit. Also the steel used for mechanical fasteners is able to deform in a distinctly plastic manner. Even though, not in all cases timber connections deform plastically before failure resulting in brittle failure modes. Avoiding the causes for brittle failure modes, specifically high tensile perpendicular to the grain and shear stresses, leads to distinctly plastic failure modes of connections with mechanical fasteners. This case is preferable in timber structures.

Based on technical innovations regarding engineered wood products as well as fastener and steel technology, high-performance timber connections were developed in recent years. High-performance connections often are carried out as reinforced connections. The reinforcement relates to the timber in the connection area, where especially tensile stresses perpendicular to the grain are transferred by the reinforcement. The cross layers of cross-laminated timber members act as reinforcement; hence joints in CLT also show high potential for ductile joints.

This paper deals with modern timber joints that are designed in such a way that brittle failure is avoided and ductile behaviour can be achieved by using cross-laminated or subsequently reinforced members. The improvement of the ductility levels is shown based on several experimental studies comparing non-reinforced to reinforced connections.

The failure mechanisms as well as the common reinforcement techniques are also shown. Due to the highly nonlinear behaviour of timber joints, the definition of ductility is also discussed.

2. Fundamentals about timber joints

When considering timber connections, the joints can be classified into three types:

- Carpenter joints.
- Glued joints.
- Joints with mechanical fasteners.

Carpenter joints are mainly used to transfer compression forces. If ductility is observed within these connections, it is because of compression perpendicular to the grain failure in at least one member. Glued joints generally do not show ductile behaviour, their failure is brittle. Joints with dowel-type fasteners are potentially ductile "by nature" due to the interaction between the highly nonlinear behaviour of the wood under embedding stresses and the bending behaviour of the steel fasteners. The challenge is to avoid the brittle failure mechanisms described in Section 2.3 by either avoiding perpendicular to the grain tensile stresses or by using reinforcement techniques described in Section 2.4.

2.1. Embedding behaviour of timber

Mechanical fasteners in timber members loaded perpendicular to the fastener axis cause embedment stresses and subsequent deformations in the surrounding wood. Due to the mostly circular cross-section of the fasteners, the wood is compressed both,

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