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Consideration of plasticity within the design of timber structures due to connection ductility

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ABSTRACT

The plastic behavior of fasteners in timber structures has gained more and more interest within recent years. In particular, dowel type fasteners show a significant ductile behavior if a certain embedded length of the dowel is ensured. The embedded length is either found by using the formulas based on the design codes (DIN (2008) [3], DIN EN 1995-1-1 [4], etc.) or by verifying the slenderness ratio λ (Jorissen (1998) [5] and Mischler et al. (2000) [32]). A further important issue is the prevention of splitting of the timber itself. Full threaded self-drilling screws enable an effective method to prevent the connection of such a failure (Bejtka (2005) [10]).

Most of the inherent material properties of timber, except the behavior in compression, do not allow a plastic design in pure timber structures. Connections accomplished with dowel type fasteners however enable to bridge that gap. The ability of forming plastic hinges by ductile joints within statically undetermined systems provides substantial advantages for a structure. First and foremost, the capability to dissipate energy provides some benefits, such as the integration to the earthquake analysis and in addition to increase the robustness of the structure. A load redistribution within statically undetermined systems can also be achieved, and thereby the possibility of a higher utilization of the structural system.

Within this paper, the possibility to redistribute internal forces in timber structures is shown and some application criteria to form plastic hinges are given. Since timber is an inhomogeneous material and is characterized by the scattering of the material properties, the influence of the scattering of the modulus of elasticity to the required rotation of the joint is presented.

In order to implement the ductility to timber structures, it is necessary to appraise the ductility as an interaction of the different types of fasteners within timber. Based on conducted experiments the evaluation of the displacement at the point of yielding with respect to existing appraisal models is discussed. Furthermore, different existing methods to evaluate the point of yielding and the ductile behavior of fasteners in timber structures are discussed.

1. Introduction

The plastic behavior of connections in timber structures has gained more and more interest in recent time. The theory of Johansen [1], and Meyer [2] for the calculation of dowel type fasteners is based on developing plastic hinges within the fastener, and is nowadays state of the art not only in Germany [3], but also in Europe [4]. This type of connectors show a significant ductile behavior if a certain embedded length within the timber is ensured, and the connection is not endangered due to the splitting of the timber. The required timber thickness (t_{req}), in order to form plastic hinges within dowel type fasteners, is given in DIN 1052 [3]. Furthermore, the ratio of the timber thickness (t_i) to the diameter (d) of the dowel gives an approach for predicting the ductile behavior of a connection. The dowel slenderness ratio for timber to timber connections is given by

$$\lambda = \frac{t_i}{d} > \begin{cases} 1,39 \cdot \sqrt{\frac{f_y}{f_h}}, & \text{for side members} \\ & \text{[5, Table 2.3]} \\ 1,15 \cdot \sqrt{\frac{f_y}{f_h}}, & \text{for middle members} \\ & \text{[5, Table 2.3]} \end{cases} \quad (1)$$

with f_y : yield strength of the dowel type fastener in bending
f_h : embedment strength

to develop plastic hinges within the connection.

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