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Reinforcement of dowel type connections

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HIGHLIGHTS

- A good design of dowel type fasteners is essential to ensure safe designs.
- Failures that occur in dowel type connections are mostly brittle.
- Failures encountered occur because of an excess of shear or tensile stresses.
- Self-tapping screws will be the main focus of this report.

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ABSTRACT

A good design of dowel type fastener connections is essential to ensure safe designs for the whole structure and cost effective solutions. With reinforced connections, engineers can achieve better capacity of the connection and safer designs by increasing the ductility of the connection (so-called "capacity design" with a ductile connection to be the weak point). This paper presents an overview of the reinforcement of dowel type connections. Most of the failures encountered in dowel type connections occur because of an excess of shear stresses or tensile stresses perpendicular to the grain in the connection area. Because of the large amount of situations and reinforcement techniques, this report mainly focuses on the reinforcement of dowel-type connections when the dowels are mainly loaded parallel to the grain. For such connections, modes of failure of un-reinforced and reinforced connections, updated design models and the effect of the reinforcement on the ductility of the connection will be presented. Among the various types of reinforcement techniques available, nowadays, self-tapping screws have found a wide field of application and they will be the main focus of this report.

1. Introduction

In timber structures, the design of dowel type connections may govern the overall design of structural members. Because of the low load-carrying capacity of one fastener (when considered alone) relative to the total load supported, designers have to design for numerous fasteners and deal with regulations relating to the minimum spacing requirements. Because of the weakness of timber in shear and in tension perpendicular to the grain, spacing requirements are mandatory to avoid any failure of connections at very low load rates (compared to the ultimate load of the global structure). Spacing requirements may lead to a global over sizing of the timber members that is of course detrimental to the cost effectiveness of the solution. Designing large joints (with large spacing between the dowels) may result in uneconomical solutions and potentially lead to problems caused by shrinkage that is the result of variations in the timbers moisture content. In that situation, the use of some types of reinforcement is an opportunity to ensure a better design.

Various reinforcement techniques have been proposed among them, truss plates [2,3], fibreglass [4,5], threaded rods [6], glued in rods and self-tapping screws (STS) [7] or glued-on wood-based panels [8]. All of them mainly aim to avoid splitting of the timber in the joint area. Some examples are presented in Fig. 1.

Haller et al. [9] have used multiaxial stitch bonded and biaxial weft knitted textiles (Fig. 1d). This investigation concluded that even light textile reinforcements may significantly increase the strength, the stiffness and the ductility of doweled joints. It appeared from embedding tests that loop-like fibre placements achieved the highest embedding strength and stiffness, whereas biaxial knitted fabrics result in more ductile connection behaviour. However, special attention has to be paid to any solution involving the wrapping the timber connections in an airtight textile because of the risk of decay.

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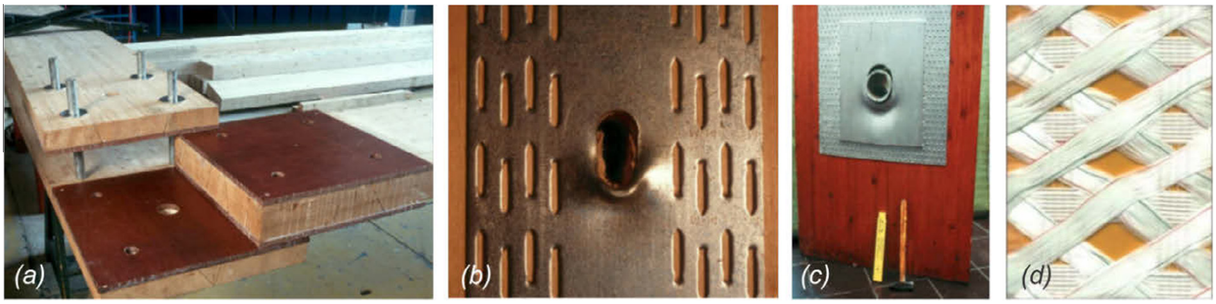


Fig. 1. (a) Reinforcement using glued-on boards (b) reinforcement by punched metal plate fasteners and (c) nail plates [8] (d) multiaxial stitch bonded fabric [9].

Most of the failures encountered in dowel type connections occur because of an excess of shear stresses or tensile stresses perpendicular to the grain in the connection area. Because of the embedment of the fastener into the wood, very complex stress states appear in the wood along the contact surface (including shear stress and tension perpendicular to the grain). The relative importance of those stresses depends on the load at an angle to the grain and different failure modes may occur as presented in Fig. 2.

Reinforcements help to overcome timber weaknesses by increasing the shear strength and the tensile strength perpendicular to the grain and by stopping the propagation of cracks. This report mainly focuses on the reinforcement of dowel-type connections when the dowels are loaded parallel to the grain (Fig. 2a). For such connections, modes of failure of unreinforced and reinforced connections, proposed design models and the effect of the reinforcement on the ductility of the joint will be discussed.

Situations where dowels are loaded perpendicular to the grain are not developed in a large extent here after. One may notice that in that situation reinforcements (screws, glued in rods or a surface reinforcement as a plate) prevent crack propagation (Fig. 3). This kind of reinforcement have been studied by several authors, among others, Franke et al. [19], Borth et al. [20], Schoenmakers et al. [21], Jensen et al. [22] and Leijten [23]. Schoenmakers et al. [18] have studied the reinforcement by screws and tested several configurations (different relative heights h and loaded edge distances h_e) as presented in Fig. 3. Blass et al. proposed a design model that assumes that timber has no tensile strength perpendicular to the grain [25].

Initially for assembling elements (member or joints), STS have found a new field of application with the reinforcement of timber beams or timber joints. The benefits of using STS are generally their efficiency (as reinforcement), their low costs (cheaper than other reinforcement materials) and the fact that they are easy to use (the setup is less complex than for glued in rods for example). Moreover, the use of STS does not require any surface preparation or pre-drilling (for the smaller diameters) and new screw-guns enable fast and effective installation of STS. Reinforced with STS, connections may behave plastically until failure (because any splitting of wood is prevented). STS, contrary to traditional wood screws, are fully threaded and made with high tensile strength steel. They can bear high axial loads (even with a small diameter, reducing the danger of the splitting of wood) and have high withdrawal strength due to their improved thread geometry. Due to the rapid growth in the uses of STS for reinforcements, they will be the main focus of this report.

2. Reinforcement of dowel-type connection with self-tapping screws

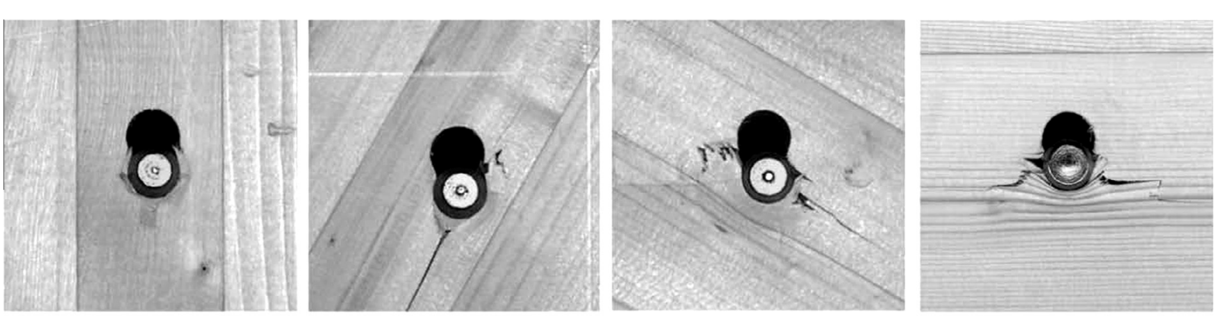
2.1. Modes of failure of an unreinforced dowel-type connection

The different failures modes of a joint made with dowel-type fasteners are presented in Fig. 4. Five failure modes are indicated depending on the connection geometry: edge and end distances of the fasteners, spacings, the fastener diameter (in relation to the thickness of timber) and the number of fasteners.

The failure mode (a) is ductile because it is characterised by the embedment of the fasteners into the wood, the others are not [8,10–12]. Timber may show a tendency to split in the connection area before the embedding strength is reached according to timber thickness, diameter and number of dowels, load to the grain angle, spacing as well as the end and edge distances of the dowels.

2.2. Self-tapping screws

STS with the thread running along the full length (Fig. 5i) and screwed perpendicular to the grain increase the local strength and tension perpendicular to the grain so they counteract the tendency of timber to split. This reinforcement is achieved by ensuring that the tensile stresses perpendicular to the grain are mainly supported by the screws and not by the timber. By protecting against any premature brittle failure with this technique, the connection



(a) $\alpha = 0°$ (b) $\alpha = 30°$ (c) $\alpha = 60°$ (d) $\alpha = 90°$

Fig. 2. Failed embedment specimens tested at different loads to the grain angles: (a) dowel loaded parallel to the grain, (d) dowel loaded perpendicular to the grain [1].