Perspectives in Science (2016) 7, 261—265

Available online at www.sciencedirect.com

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journal homepage: www.elsevier.com/pisc

Round timber bolted joints reinforced with modified washers and self-drilling screws☆

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Received 23 October 2015; accepted 19 November 2015
Available online 12 December 2015

KEYWORDS
Round timber;
Joint;
Reinforcement;
Self-drilling screw;
Washer

Summary Timber constructions made of round timber components are becoming more and more popular. Given that in the current European standards for the design of timber structures, timber-to-timber joint type is solved only for squared timber. This paper presents results of static tests in tension at an angle of 0°, 90°, 60° to the grain of round timber bolted joints. This research looks into reinforcement with modified washers or self-drilling screws, as these are the least labour-intensive (while economically advantageous). The joints samples were experimentally tested in the laboratory of the Faculty of Civil Engineering VŠB TU Ostrava.

Introduction

Timber constructions made of round timber components have become vastly popular. Current trends in the field of tourism and leisure industry use eco-structures that are environmentally friendly and made of natural materials. Round timber structures (milled or just stripped of bark) meet these requirements adequately. These are view-towers, bridges for pedestrians, visitor centres in natural parks and a ZOO, or other landscape conceptions. Timber constructions development was, to a certain extent, restricted in the second half of the last century in the Czech Republic. Recently, builders have begun to recourse to timber structures yet again, thus following in a long tradition of using timber as a construction material. In 2011, the highest round timber view-tower in central Europe was opened to the public in village Bohdaneč (Straka and Šmak, 2011; Fojtík et al., 2015).

The tower reaches a height of almost 53 m (Fig. 1).

If these constructions are created with truss supporting system (e.g. view-towers, pedestrian bridges), elements connections are often designed of steel bolts with embedded steel plate. In the current European standards for the design of timber structures (Eurocode 5, 2006), the issue of timber-to-timber joint type is addressed only for squared timber, which makes the pinpointing of the round timber bolted joints carrying capacity near-unfeasible due to the insufficient support in the current standards. One of the key prerequisites of the effective use of timber as a construction material is the guarantee of material technical parameters. Prior to round timber material being used in

☆ This article is part of a special issue entitled ''Proceedings of the 1st Czech-China Scientific Conference 2015''.

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http://dx.doi.org/10.1016/j.pisc.2015.12.001

Figure 1 Various types of round timber view-towers.

a construction, its technical properties have to be checked and verified. Mechanical reinforcement possibilities of round timber bolted joints were investigated and tested in the laboratory of the Faculty of Civil Engineering in Ostrava.

Reinforcement design

Timber as a material is characterized by a brittle mechanical behaviour, which means only a relatively small deformation, can be measured before the members fail. Given that this phenomenon is not desirable when designing constructions, a certain high level of deformability of joints is looked for in the design of the connections lest a splitting of the connected parts occur. Elastic—plastic behaviour of joints with sufficient joint ductility is ideal.

As apparent in Fig. 2, for some fasteners, an initial slip occurs. If the fastener is loaded, it comes into contact with the hole until it is pressed completely against it (embedded). As the load is increased yet further, a linear (more or less) behaviour between the loading and displacement can be found. Should the joint have scant deformation capacity before it reaches the ultimate load (in other words brittle behaviour), the failure occurs without a prior warning.

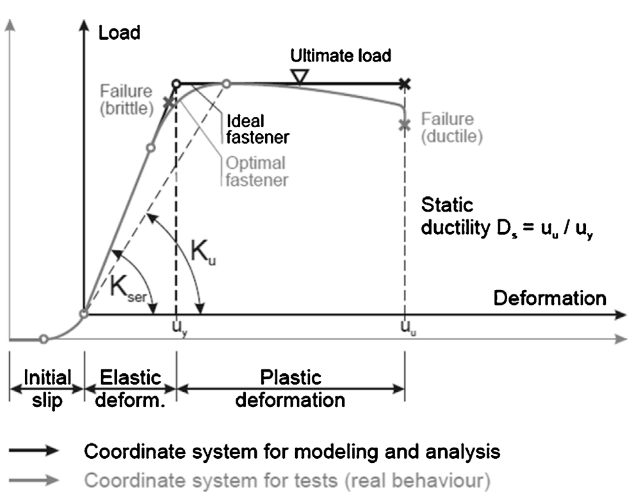

Figure 2 Typical load-slip-curve of joints (Augustin, 2008).

On the other hand, ductile joints are characterized by significant deformations before they reach the ultimate load, thus a ductile failure mode is more than desirable in well-designed joints (Augustin, 2008).

From a technical point of view, the joints have met the following key requirements: load carrying capacity, stiffness and ductility. Load carrying capacity and effectiveness of every joint is demarcated by the connected elements and the way the internal forces in the joint are transferred or rather distributed. In order to increase the load carrying capacity of a joint, and especially its ductility, it is expedient to further reinforce the wooden element in an area of the joint, which will encourage the joint's ductile behaviour.

Thus, a means of strengthening is designed as an element working in wood in the proximity of a dowel in a direction perpendicular to the grain, and in doing so causing the strengthening and clamping of the wood, thus increasing the resistance against a crack occurrence as well as splitting. Wood in tension shows low plasticity and gets damaged by a brittle fracture (Smith et al., 2013). In the case of unreinforced joints being damaged, the splitting of the wood underneath a dowel would come about very soon and very shortly after the first crack appeared, when, generally, the load carrying capacity in tension perpendicular to the grain is exceeded and the cross ties within the fibres are torn (Blass and Schädle, 2011). Not only was the aim of the reinforcement to increase the joint load carrying capacity, but, equally importantly, to increase the safety of the joint by increasing the plastic deformation preceding the ultimate joint destruction. The destruction of the joint does not come about as fast and unexpectedly as it does with unreinforced joints.

Self-drilling screws for wood with double thread 6.5 mm × 90 mm (company SFS Intec) were used for this reinforcement. The screw was placed in a longitudinal direction 40 mm off the dowel axis, and 20 mm of the round timber edge in a cross direction. For the modified washers approach, the washers were made from steel plate with a thickness 6 mm, category S235. The dimensions of these plates were 60—100 mm. Holes with a diameter of 22 mm were used. The washers were rounded to fit tightly to the round timber sample, and the wood in the bolt area was clamped tightly as well.