

Selected Problems in Using Round Timber in Building Structures

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Abstract. The content of this paper are possibilities of using round timber in various public facilities structures (e.g. children's playgrounds) and in engineering constructions (e.g. watchtowers, bridges and footbridges). Specific problems of designing round timber structures, mainly in joints, are presented here.

Introduction

Over the last decades the use of round timber constructions has increased significantly. Current trends support the use of ecological constructions. These structures are environment friendly and emphasize the use of natural and renewable building materials. Round timber structures (milled or simply stripped of bark) meet all these requirements. Various view-towers, pedestrian bridges, visitor centers in natural parks or in the ZOO, playground equipment and other landscape structures are built from round timber logs. In all the cases the structural systems were used as an interesting architectural feature.

Types of Timber Structures Made of Round Timber

At present children's playgrounds, which are made of natural round timber (see Fig. 1) or shaped round timber (see Fig. 2), are very popular.



Fig. 1 Playground made of natural round timber (left)



Fig. 2 Playground made of shaped round timber (right)

Round timber can be used also in timber footbridges constructions and bridges with smaller span. Example of a footbridge made of round timber in Orlová is in Fig. 3.



Fig. 3 Footbridge in Orlová (left)



Fig. 4 Lehmilahti bridge (Finland), photo - [1] (right)

Example of timber bridge made of round timber with 19 m span is in Fig. 4.

The tallest round timber view-tower in central Europe was built in Lázně Bohdaneč in the Czech Republic; the height of the tower is almost 53 m (see [2] and Fig. 5). The tower was opened in 2011. The whole tower was made of natural round timber (spruce) and bolted joints with slotted-in steel plates.



Fig. 5 View tower near Lázně Bohdaneč

Several interesting view-towers were built near Uherské Hradiště. One was built in combination of round and sawn timber and bolted joints with slotted-in steel plates (see Fig. 6). Another one was built only from round timber and bolted joints (see Fig. 7).



Fig. 6 View tower in Polešovice



Fig. 7 View tower in Vlčnov

Types of Joints

Several types of joints can be used in round timber structures, e.g. carpenter joints, nails, screws, steel bounds, but nowadays bolted joints or bolted joints with slotted-in steel plates (see Fig. 8) are most popular.



Fig. 8 Example of a round timber bolted joint with slotted-in steel plates

Research of Bolted Joints with Slotted in Steel Plates Carrying Capacity

Element connections are often made from bolts with slotted in steel plates, especially for truss structures. These connections are the weakest part of structures. Mechanical reinforcement possibilities of round timber bolted joints were researched and tested in a laboratory of the Faculty of Civil Engineering. However, at present there is little information available about timber joints reinforcement, and the design standards (e.g. [3]) give few guidelines. For more information – see [4, 5].

Test Samples

All the test samples were made of spruce wood. A few nondestructive tests were carried out before the start of static tests in the press. The test samples were weighed on a laboratory scale, their moisture and dimensions were measured. The thickness of the annual rings and the slope of grain were also measured. The density was determined on the basis of measured values. The average moisture was 12,4 %. The average value of apparent density reached 480 kg/m^3 (with standard deviation 88 kg/m^3).

It was necessary to adapt the dimensions of the test specimens to dimensional possibilities of the laboratory machinery. Thus, the specimen length was 450 mm, and the diameter was 120 mm. The bolts made of high strength steel (category 8.8) were used. The connection plates were made of steel

S235. The plates had a thickness of 8 mm, length of 290 mm and width 80 mm. Holes in steel plates and timber with diameter 22 mm, respectively, 20 mm were used. The holes distance to the free end in the timber was 140 mm; in the steel 50 mm. Several specimens were made without reinforcement. The others were reinforced in a various way (with special washers, screws, steel plates and nails etc. – see Fig. 10).

Course of Tests

The specimens were subjected to a simple tension test (see Fig. 9). The tension force (samples were loaded parallel to the grain) was increased gradually. The displacement rate choice of the press jaws was optimal because the failure of all the specimens appeared in a time-boundary $300 \pm 120 \text{ sec}$, which corresponds to the current European standard [3]. Test parameters were the same for all the specimens.

At first, unreinforced specimens were tested. The average value of carrying capacity in tension was 67 kN (with standard deviation 15 kN). All the testing specimens were damaged by splitting. The embedment underneath the bolts grew during loading, and the crack was initiated. During the next loading, the crack grew rapidly and uncontrolled until the final damage. The sample failures were caused by reaching the critical tensile stress perpendicular to the grain.



Fig. 9 Laboratory press (left), a sample with modified washers in the press (right).

Reinforcement

The reinforcement design was based on the first series test results. The reinforcement relates to the timber in the connection area. The challenge is to avoid the splitting failure mechanisms. The reinforcement is supposed to have two basic effects: tensile stresses perpendicular to the grain are transferred and the embedding capacity of the reinforced timber area increases. Several different reinforcement methods were tested - applying modified washers, common wood screws (one or two under each bolt), BOVA plates and applying steel bands.

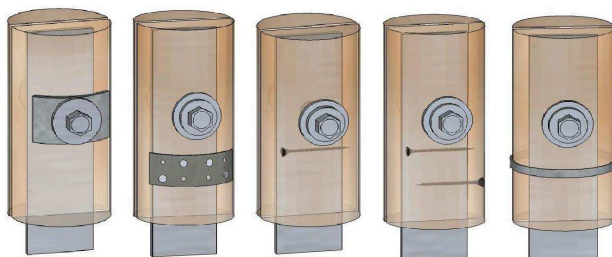


Fig. 10: Reinforcement methods: (from left) modified washers, BOVA plate, one screw, two screws, steel band

For the modified washers approach, the washers were made from a steel plate with thickness 8 mm, category S235. The dimensions of these plates were 60 mm to 100 mm. Holes with a diameter 22 mm were used. The washers had been rounded to fit tightly to round timber sample, and the wood in the area of the bolt was clamped firmly. BOVA plate is a steel plate with a thickness of 2 mm and dimensions of 40 to 120 mm, provided with holes for nails. The plate was fastened to a sample with four nails. Plates were bent according to shape of the sample.

For the common wood screws approach, the tested screws had a diameter of 5 mm and length of 90 mm. One or two screws were located under each bolt (in the direction of loading). The screws were oriented perpendicular to the grain. The last method is to tighten the end of the samples with a steel band. The band has a thickness of 0,9 mm and width 9 mm.

Results

The average carrying capacity in tension of the samples with modified washers was 72,7 kN. Cracking and subsequent growth were decreased. In the case of samples with screws, during the sample testing, no failure due to the crack occurrence was observed. Displacement was increased up to the failure. All the observed failures were caused by the plug shear. The average carrying capacity in tension of these samples was 72,4 kN (with standard deviation 19 kN). Decreased rates of cracking and subsequent growth were observed on the reinforced samples. Furthermore, plug shear failures were observed in the case of reinforcement by applying wood screws.

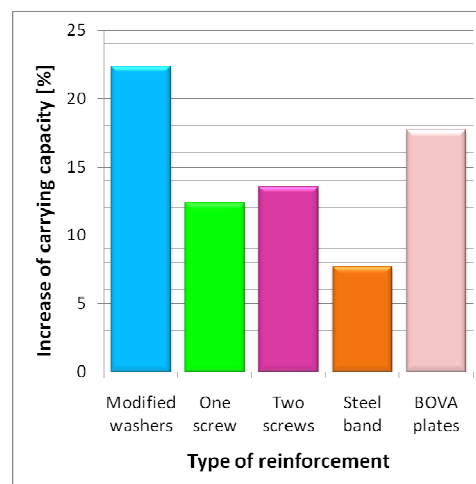


Fig. 11: Comparison of effectivity of reinforcement methods

Fig. 11 shows that reinforcing by means of the modified washers and BOVA plates demonstrates the highest increase in carrying capacity. In terms of implementation simplicity, reinforcing using two screws appears to be the most effectual.

Summary

The reinforced samples were able to absorb around 20 % more of the pressure before cracking than the unreinforced ones. Both of the reinforcing methods are economically profitable due to the usage of affordable parts. However, as the number of samples is small, the presented results are prone to a statistical error. Due to the relatively high carrying capacity dispersion of the round timber and the bolted joints with the slotted - in plates it is reasonable to consider using some of the fully probabilistic methods e.g. [6, 7, 8] for the reliable and safe design and assessment of this type of structures and joints.

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